OHIO CLIMATE ROAD MAP

O·H·I·O ENVIRONMENTAL COUNCIL
KEEP WATCH. TAKE ACTION. MAKE CHANGE

PART TWO
JUNE 2006

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The mission of the Ohio Environmental Council is to inform, unite, and empower Ohio citizens to protect the environment and conserve natural resources. The Ohio Environmental Council works behind the scenes and on the front lines of Ohio's most critical environmental-conservation battles. For more than 35 years, citizens across the state have counted on the OEC to be their voice at the Statehouse and state agencies—fighting to protect Ohio's environment through the promotion of sound environmental laws and policies.

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FOREWORD

Ohio must prepare to live in a world where new, low emission technologies are needed in order to limit the rise of global temperatures. If we act sooner rather than later, we can lay the foundation for our energy security and economic health.

Major Ohio-based companies and political figures have announced their support for mandatory limits on greenhouse gases. Many businesses are beginning to develop "hedge" strategies by initiating voluntary reduction measures in order to prepare for an emissions-constrained world in the near future. The most far-sighted are investing in "climate-friendly" technology advances. The best available science indicates that we will have to make significant reductions in greenhouse gas emissions to limit global temperature growth. These changes will require broader use of some existing technologies as well as deployment of new technologies and energy systems.

Ohio has the potential be on the forefront of those changes. Ohio's geology, fertile soil, and manufacturing know-how position our state to be a major supplier of climate technology solutions. On the other hand, our ranking as the third largest emitter of heat-trapping carbon dioxide in the country places us at a severe disadvantage–*unless we start investing in solutions immediately.*

Part One of the *Ohio Climate Road Map*, released in June of 2005, detailed the scope of the climate stabilization challenge from Ohio's perspective; identified sectors of Ohio's economy poised to become suppliers of climate technology solutions; and demonstrated how these technologies can help us meet the challenge ahead. In **Part Two**, we provide very specific policy and action recommendations to move technology development and deployment forward in nine key areas: bio sequestration and products, advanced coal generation and carbon sequestration, electric heating and efficiency, methane, vehicle efficiency, wind and solar, building greenhouse gas markets, hydrogen/new energy systems, and clean diesel.

If we take proactive measures, traditional Ohio industries (coal, agriculture, and auto manufacturing) as well new industries (efficiency, wind, solar, and fuel cells) can be economic winners while meeting some of the greatest challenges of our time–energy security and climate change. If our government, businesses, concerned communities, and citizens fail to work together, we will all pay the price–both economically and environmentally.

We hope this road map will be a catalyst for positive action. We stand ready to work with all parties to develop sensible, sustainable solutions for Ohio.

Vicki L. Deisner
Executive Director
Ohio Environmental Council

MEASURING SUCCESS

Part One of the *Ohio Climate Road Map* outlined the need for and potential pathways to achieve a limitation on global warming to 1°C over the next century. One possible path outlined included significant reductions in multiple greenhouse gas emissions over several decades. For Ohio, the share of our state's reductions could look like the targets laid out in Table 1.[1]

Emission reductions in Ohio that would contribute to climate stabilizationñ
in Million Metric Tons of Carbon Equivalent (MMTCE)

Greenhouse Gas Pollutant	Emissions in Year 2000 (MMTCE)	Target emissions level (MMTCE)	Target year for emissions reduction
Carbon Dioxide	71.75	26.00	2100
Methane	5.12	1.54	2035
Nitrous Oxide	3.62	1.81	2035
Elemental (black) carbon	2.70	0.27	2020

Table 1

Measuring Success for Carbon Dioxide Reductions

Carbon dioxide (CO_2) has one of the longest lifetimes of all the greenhouse gases. Once CO_2 is emitted into the air, a portion of it will remain in the atmosphere for over 200 years. Even if global emissions were to stay constant over the next 100 years, concentrations of CO_2 would build up in the atmosphere. Therefore, there is a finite amount of CO_2 that can be emitted through the end of this century if a growth in temperature is to be limited.

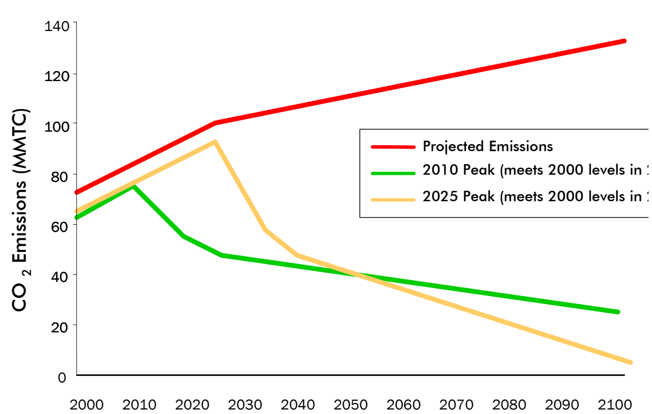
The total amount of CO_2 that is emitted over a period time is known as a "carbon budget". Based on the estimated future growth in CO_2 emissions, Ohio's 100 year carbon budget is 10,975 million metric tons of carbon (MMTC). If we act to limit global warming, Ohio's 100 year carbon budget will need to be no more than 4,540 MMTC.[2] The area under each 100 year emissions reduction path in Figure 1 is equal to 4,540 MMTC.

There are three primary sectors that are sources of carbon dioxide emissions–the power or electricity sector, the transportation sector, and the thermal sector (residential and commercial heating and industrial processes). If the total carbon budget is subdivided into these three sectors, the sector budgets would be:
Power–2,010 MMTC;
Transportation–1,463 MMTC; and
Thermal–1,066 MMTC.

Near-term Carbon Budget Savings

Reducing carbon dioxide emissions sooner rather than later is critical, because waiting too long to make cuts will require a much shorter and aggressive transition to cleaner technologies, and meeting the long-term annual emissions reduction target will be that much more challenging. In other words, if we emit or "spend" a lot of our carbon budget up front, we will have much less to emit or "spend" later.

550 ppm Stabilization Path with
Emissions peaking in 2010 and 2025



SOURCES: U.S. Department of Energy, Electric Power Research Institute, O'Neil

Figure 1

Long-term Carbon Budget Management

The ultimate measure of success will be based on how effective technologies are at reducing emissions to very low levels over the next hundred years. It is not enough to just make small emission cuts in the near-term. To live within the carbon budget, we need deep emission cuts in the long-term. Meeting these deep reductions will require a transition from many of our current technologies to new advanced technologies.

Measuring Success with Other Greenhouse GasesñìQuick Coolingî

Other greenhouse gas emissions have a much shorter atmospheric lifespan than carbon dioxide. Methane emissions persist in the atmosphere for no more than 10 years. Black carbon persists for only a matter of weeks. As a result, the cooling benefit from reducing these other greenhouse gases occurs very quickly. Many of these emissions can be addressed through existing and relatively affordable technologies. Therefore, the measure of success for these greenhouse gases will be whether we make very deep cuts in them over the next decade or two.

BIO SEQUESTRATION AND PRODUCTS

Ohio should promote a robust bio products industry as part of its effort to reduce greenhouse gases. These efforts should focus on commercializing the proven technologies of today, as well as promoting the development of new technologies that hold economic and environmental potential. Bio technologies can take Ohio 28% of the way to where we need to be with respect to annual CO_2 emissions by mid century.

Technology Options

Biological Sequestration

Biological sequestration is the process of removing carbon from the atmosphere and storing it over long periods of time in biomass or indefinitely in soil.

Conservation Tillage

Conservation tillage, often called no-till farming, differs from conventional or “disc” tillage in that crops are grown with minimum cultivation of the soil. Because the soil is left relatively intact, the carbon that has been absorbed into the soil through crops will remain there, rather then be re-emitted to the atmosphere as with conventional tillage. In addition, the maintenance of cover crops helps to reduce soil erosion, thereby reducing the re-emission of carbon from soil disturbance to the atmosphere. According to recent research by The Ohio State University[3], switching from conventional tillage to no-till farming in Ohio could sequester an estimated 71 MMTC over a 25 year period, or an estimated average of 2.84 MMTC per year.

Forestry Management

There are several potential methods for improving a managed forested area’s ability to act as a carbon sink over a century or more. Examples include regular light harvesting that targets material likely to die and decompose between harvests and early commercial thinning that removes trees which are losing their competitive position relative to the canopy. Recent forest growth and harvest trends in Ohio forests have resulted in a net sequestration of carbon on the order of 7.42 MMTC annually.[4] This is primarily due to the growth of forests on fallow agricultural lands outpacing the harvesting of timber. It is unclear how long this trend may continue, or how it may be influenced by other factors–such as the maturing of newer forests. It may be possible that by adopting these forest practices in Ohio the “business as usual” sequestration activity in Ohio could be improved. However, substantial analysis is necessary to determine which practices would be effective and by how much.

Bio Char

Charcoal fertilization is a process in which biomass is turned into char by pyrolysis and may be infused with soil nutrients (such as nitrogen) and applied to farm fields as an alternative to conventional fertilizer (e.g. synthetic nitrogen fertilizers). In addition, initial indications are that char–if properly produced–also enriches soil microbial activity, potentially improving the ability of the soil to capture and store carbon. As an added benefit, char fertilizer appears to release nitrogen much more slowly than conventional fertilizers, thus potentially reducing “excess” nitrogen application to crops and reducing nitrous oxide emissions from fertilized crop land. While more research needs to be undertaken before reliable estimates can be made, the primary potential greenhouse gas reduction advantages for bio char are:

- Locking carbon into char form for centuries
- Reducing nitrous oxide and methane emissions from farm fields
- Potentially improving the ability of soils to sequester carbon
- Generating bio fuel or oil as a byproduct of char production through pyrolysis

Bio Products

Bio material can be turned into a variety of products. Bio material feed stocks include crops, crop waste, timber, wood processing waste, animal waste, and food processing waste. Products include fuels, construction materials, building materials, bulk chemicals, specialty chemicals, and polymers. The two primary ways these products can reduce greenhouse gases are by substituting for the use of fossil fuels or by having the carbon in the biomass turned into a durable product. The two primary ways to process bio products are thermal (heat) or metabolic (biochemical).

Thermal Processes

Bio material can be turned into fuel or other products through thermal processes such as combustion, gasification, or pyrolysis.

- An example of biomass combustion would be the co-firing of coal and bio mass in a conventional coal plant. The greenhouse gas benefit comes from the displacement of the fossil fuel (carbon from geologic formations released into the atmosphere through burning) with bio fuel (carbon from the atmosphere stored in biomass and re-released through burning).
- Biomass gasification is the use of high temperatures to convert biomass into a synthetic gas or "syn gas" made up of hydrogen and carbon monoxide. As with coal gasification, this syn gas can be combusted to generate electricity or converted into fuel, bulk chemicals, or other products. When carbon sequestration is added to biomass gasification, the greenhouse gas emissions can actually become negative, because the bio material acts as a conduit to move carbon from the atmosphere to permanent geologic storage.
- Fast pyrolysis is the rapid decomposition of biomass by heat in the absence of oxygen, which produces gases (hydrogen, carbon monoxide and methane), bio-oils, and char. The primary products from pyrolysis are char, oils and gases; the gases can be combusted for heating use.

Metabolic Processes

Metabolic processes turn bio material into products through biochemical paths ranging from fermentation to bio-engineered bacteria. Products include fuels such as ethanol and bio diesel, and manufactured goods such as bulk chemicals and polymers.

- Biochemical processes–metabolic processes use biochemical pathways to produce products; for example, fermentation producing ethanol and esterification/transesterification producing bio diesel.
- Bio-engineered bacteria (bio factories)–bio factories include genetically engineered bacteria as part of their biochemical process. DuPont has recently developed a "cell factory" approach to manufacturing the chemical building blocks for its high performance polymer, Sorona®.

Recommended Measures

Promoting Biologic Sequestration

State Tax Credit for Conservation Tillage Equipment

The state of Ohio should consider adopting a state tax credit for farmers that purchase conservation tillage equipment. This could take the form of an income tax credit or an accelerated depreciation schedule. The state of Maryland offers a 100% tax credit for the purchase of conservation tillage equipment. Virginia and North Carolina allow up to a 25% tax credit for the purchase of conservation tillage equipment.

Equipment Purchasing Cooperatives

Farmers should be encouraged to develop equipment purchasing cooperatives for transitioning to conservation tillage practices. This could reduce costs and allow farmers a wider variety of options with respect to which type of conservation tillage practice best suits their needs.

Crop Insurance for Conservation Tillage Transition Period and Carbon Liability

Farmers moving from conventional tillage to conservation tillage face an increased risk of lower crop yields during the initial three to five years of transition. Farmers also face financial liability issues with respect to selling carbon credits based on conservation tillage, only to lose soil carbon due to flooding and other natural disasters. Crop insurance programs are government-private sector programs that help manage the economic impacts of crop loss on farmers. A crop insurance program directed at yield loss for the transition period, or for soil carbon loss, could help address these potential barriers.

Limited Property Tax Credit for Conservation Tillage

Another method of addressing the conservation tillage transition issue is through limited property tax relief. The Current Agricultural Use Value (CAUV) assessment is a program that allows farmers to have their parcels taxed according to their value in agriculture, rather than full market land value. The State of Ohio should consider including a one-time, three to five year adjustment to the CAUV that reflects the increased crop loss risk during the transition period.

FOUNDATION FOR ACTION

The Ohio Air Quality Development Authority and the Ohio Coal Development Office are participating in the Midwest Regional Carbon Sequestration Project (MRCSP). This program is sponsored by the U.S. Department of Energy and is focused on moving the research and development of carbon sequestration forward through small initial test projects in the region, including a focus on agricultural soil sequestration. The OEC is supporting and participating in this project.

In February 2006, Governor Taft increased the State of Ohio's commitment to bio fuels by doubling E85 ethanol use in the state fleet from the current rate of 30,000 gallons to 60,000 gallons in 2007 and increasing future use by 5,000 gallons each year thereafter; increasing bio diesel use in the state fleet by 10%; purchasing only flex-fuel vehicles that can run on both unblended gasoline and E85 ethanol blend as state vehicles are replaced (Ohio already has 1,710 flex-fuel vehicles); and tripling the amount of E85 pumps available to Ohio consumers by the end of 2006. The OEC supports this initiative.

The Ohio State University Carbon Management and Sequestration Center focuses on understanding and enhancing the science, management, and policy of carbon within terrestrial soils, crops, trees, and wetlands. The Center is led by Dr. Rattan Lal, one of the most widely respected authorities on the issue, and a lead author for the Intergovernmental Panel on Climate Change's (IPCC's) Special Report on Land Use, Land Use Change, and Forestry.

Ohio's Third Frontier program recently provided $11 million to develop the Ohio Bioproducts Innovation Center at the Ohio Agricultural Research and Development Center. The Center will focus on research and development of a broad range of chemical industry products (adhesives, composites, specialty chemicals and hydrogen production).

As of June 2006, both the Ohio House and Senate have adopted House Bill 245. The bill would require Ohio to purchase bio fuel "friendly" vehicles, bio fuels, and create state contract preferences for companies that use bio fuels. The legislation also would create financial programs to promote bio fuels and idling reduction as well as a tax credit to promote ethanol-blended gasoline. The OEC supports this legislation.

Developing a Voluntary Greenhouse Gas Registry in Ohio–Accounting Standards for Biological Sequestration

The Ohio Department of Agriculture and Ohio Department of Natural Resources should lead efforts to consider and develop recommended carbon accounting practices for soil and forestry sequestration in Ohio. These efforts could be part of a larger effort to establish a voluntary greenhouse gas registry in Ohio or participation in regional registries, such as the LADCO project *(see section on Developing Greenhouse Gas Markets)*. Carbon accounting practices include the monitoring of carbon in the soil that has been credited for carbon sequestration. The Regional Greenhouse Gas Initiative (RGGI) in the Northeastern U.S. will permit the use of some greenhouse gas offset credits from outside the region. It is very likely other future greenhouse gas credit trading systems will allow their use as well. By engaging in the development of carbon sequestration accounting, Ohio may have an opportunity to help influence what standards eventually are adopted in the RGGI. In addition, the process will help identify accounting issues that may be particularly relevant to our region. One possible aspect of the program would be to explore and possibly promote the Voluntary Reporting of Greenhouse Gases-CarbOn Management Evaluation Tool (COMET-VR) tool. The software, developed by the U.S. Department of Agriculture, is a decision support tool for agricultural producers, land managers, soil scientists and other agricultural interests that can be used to construct a soil carbon inventory.

Improving Forestry Sequestration

Certain harvesting practices may be able to increase the amount of carbon sequestered in Ohio forests beyond current "business as usual" practices, which account for an estimated 7.42 MMTC each year. Tax incentives and other programs should be considered to promote more greenhouse gas beneficial management practices. However, before such steps are taken, more study is required in order to identify which practices will yield the best results in our region. Forest models such as HARVCARB and FORCARB can be used to identify the additional carbon sequestration potential of Ohio forests and the resulting market implications. A recent example for this type of undertaking can be seen in the joint effort to characterize forestry opportunities in New England by the U.S. Forest Service, the Maine Forest Service, and Environment Northeast.


Kenneth M. Gale

Next Steps for Promoting Biologic Sequestration

1. The Ohio Department of Agriculture, farm groups and non-governmental organizations (NGOs) should explore with crop insurers possible designs for a conservation tillage crop insurance program, and what, if any, changes in federal law are necessary for the adoption of such a program.
2. The Ohio Department of Agriculture, in conjunction with the Ohio Department of Taxation, should work with Ohio growers, NGOs, and state agriculture and tax officials to outline a state tax policy for promoting conservation tillage equipment purchases, crop insurance programs, and CAUV adjustments and work with the General Assembly to adopt these recommendations into law.
3. The Ohio Department of Natural Resources should consult with the Maine Forest Service, the U.S. Forest Service, and Environment Northeast to identify the best methods to estimate how management practices can improve forest sequestration of carbon in Ohio using such forest modeling tools such as HARVCARB and FORCARB.
4. The Ohio Department of Agriculture and the Ohio Department of Natural Resources should develop a stakeholder committee of agriculture and forestry companies, NGOs and state agencies to develop a set of recommended accounting practices for biologic sequestration in Ohio. A dialogue should be

established between this group and the operators of the greenhouse gas trading programs (CCX, RGGI) where the greenhouse gas credits may be sold in order to ensure the accounting system developed in Ohio is compatible with the market requirements.

Promoting Bio Product Demand

State Purchase Program for Bio Fuels

The State of Ohio should adopt a procurement and contractor policy that targets the purchase of bio fuel "ready" vehicles and bio fuels. In addition, Ohio should consider a bio products procurement preference provision, similar to the federal program adopted in the federal Farm Security and Rural Investment Act of 2002.

State Tax Credit Program for Bio Fuels

The State of Ohio should develop a tax credit to promote the purchase of bio fuels in the private sector.

Renewable Fuel Standards

Ohio should develop a renewable fuels standard that requires a minimum content of renewable fuel in gasoline and diesel sold in Ohio. Minnesota has a renewable fuel standard that requires gasoline to include, on average, 10% ethanol and diesel fuel to include, on average, 2% bio diesel.

Advanced Technology Portfolio Standard

Twenty-three states have adopted a renewable portfolio standard which requires electric power suppliers to obtain a portion of their power from renewable energy sources. Pennsylvania adopted a variation of that policy which may be most applicable to Ohio, known as a "technology portfolio standard". Under Pennsylvania law, power providers have several options to meet the cleaner power requirement, including renewable energy, energy efficiency, and coal waste.

Co-firing of biomass in coal fired power plants and co-gasifying biomass in coal gasification plants would be eligible under such a program. In addition to the greenhouse gas benefit derived from substituting bio fuel for fossil fuel, biomass gasification with carbon sequestration would provide an additional benefit by transferring some existing atmospheric carbon into geologic formations *(see section on Advanced Coal Generation and Carbon Sequestration)*.

Best Environmental and Greenhouse Gas Practices for Bio Feed Stock Use

There are several critical issues relating to the potential environmental benefits and liabilities associated with using bio fuels and bio products that need to be better understood. Understanding potential challenges and identifying possible solutions will be critical for accurately promoting technologies that maximize the ability to address greenhouse gases in an environmentally and economically sustainable manner. A research agenda should be formed around the following issues:

- Land in use–A recent analysis of alternative fuels and greenhouse gas impacts identified important questions relating to the demand for bio fuels (in particular soy-based diesel). The analysis indicated that if demand for soy diesel began to result in placing currently fallow land in crop production, the additional carbon emissions from the soil and additional nitrous oxide emissions from the field would result in soy diesel usage creating a net increase in greenhouse gases relative to fossil fuel use. It is very important to more clearly understand this potential issue and how this challenge might be managed.
- Energy Balance–It is important to understand both the total greenhouse gas emissions from ethanol production and the energy balance (how much energy does it take to produce the bio fuel). While there is a range of findings on this issue, most studies find conventional corn ethanol slightly positive with respect to net energy balance and greenhouse gas emissions and cellulosic ethanol substantially positive with respect to both.[5] Ultimately, these issues need to be understood with respect to the evolving production and distribution systems.

• Crop residue and soil health–There is great interest in using crop waste, such as corn stover, for bio fuels. It is very likely this type of bio feed stock will greatly improve the greenhouse gas benefit from bio fuels. However, soil scientists are concerned that using too much crop waste will reduce the natural processes that maintain the amount of carbon in soil, which is critical for soil health and crop production. Understanding this balance is important before these feed stocks are used for large-scale fuel production.

Transparent, Standardized Interconnection

Currently, Ohio interconnection rules are based on the IEEE 1547 standards. This has provided electric power companies with considerable latitude. Further, these rules do not have any mechanism for tracking interconnection activity. The Public Utilities Commission of Ohio (PUCO) should develop a system that provides transparent tracking of how distribution companies apply these standards for each interconnection. Specific issues to be tracked should include, but not be limited to: size of generation facility, generation type (fuel, etc.), type of contract (net metering, etc.), and how utility discretion is applied.

Larger customers that are contemplating a self-generation project should consider setting up a contract under Ohio's net metering law. This may allow for interconnection at the distribution level rather than the transmission level.

Next Steps for Promoting Bio Product Demand

1. Governor Taft should approve Ohio House Bill 245 and direct his administration to make it a priority to quickly implement it.
2. NGOs and businesses interested in developing the bio products market should develop legislation to promote a state procurement preference for bio products. These stakeholders should work with the Ohio General Assembly to adopt these recommendations into law.
3. NGOs and businesses interested in developing clean energy markets should develop legislation to promote minimum use standards for advanced technology power production. These stakeholders should work with the Ohio General Assembly to adopt these recommendations into law.
4. State colleges and universities, state agencies, NGOs, and agri-business stakeholders should develop a task force to further define and help leverage new research and analysis identifying the best environmental and greenhouse gas practices for bio feed stock use.
5. The PUCO should initiate a rule making procedure to develop a tracking system for interconnection projects to better understand market activity and development opportunities.

Promoting New Technology Development

Research and Development for Bio Char Commercialization


DOE/NREL

Bio char may have the potential to be a very significant source of greenhouse gas reductions that also provides economic value to farmers. For instance, Iowa State University recently has received a $1.8 million grant from the U.S. Department of Agriculture to begin to help verify and quantify the environmental and agricultural potential of bio char from corn stover. However, many questions still will have to be answered in terms of total greenhouse gas benefits, applicability to different soils and regions, and economic value. The state universities, particularly The Ohio State University and its Ohio Agricultural Research and Development Center and the Ohio Biotechnology Innovation Center, should make researching the environmental, agricultural, and economic benefits of bio char a high priority. Members of Ohio's congressional delegation should focus on helping secure federal research funding for this effort.

Financial Incentives to Facilitate Development of the Next Technology Generation of Bio Refineries

New bio refinery technologies can be integrated into existing industries' processes. For example, DuPont integrated a pilot "bio factory" facility that produces polymer feed stock at an existing fermentation plant in Decatur, Illinois. Integrating new technologies into existing facilities can require a significant amount of engineering. In order to help promote these new ventures, Ohio should consider incentives similar to those recommended for promoting development of new coal gasification facilities, such as a tax incentive that helps offset initial engineering costs.

Next Steps for Promoting New Technology Development

1. Ohio researchers should coordinate with other existing programs to develop a research agenda for bio char that would aim to identify the greenhouse gas benefits and commercialize the technology in the next six to eight years.
2. State and federal officials should work to secure the necessary funding for the bio char research agenda.
3. Stakeholders from the bio products industry and NGOs, as well as state and local economic development interests, should work together to develop a set of incentives that address initial process development obstacles for the bio products industry and work with the Ohio General Assembly to adopt the incentives into legislation.
4. State lawmakers also should consider adopting the 2005 rider for the Ohio Energy Loan Fund on a permanent basis to fund a targeted grants program to develop advanced technology energy sources, such as advanced bio products.

Co-Benefits from Promoting Bio Sequestration and Products

Promoting bio products has several additional benefits including:

- Provides new markets for Ohio farmers
- Provides new and innovative directions for Ohio manufacturing
- Promotes domestic energy and energy security
- Conservation tillage can provide water quality benefits from reduced runoff
- Char may provide significant water quality benefits and some air quality benefits
- Char fertilizer has the potential to significantly reduce nitrogen fertilizer runoff and nitrous/nitrogen oxide field emissions–thus lessening over-nitrification of water and reducing precursors to ozone and fine particulate air pollution

Costs

Bio Sequestration

The primary cost for switching from conventional tillage to conservation, or no till, farming is the capital cost of a seed drill–between $25,000 and $65,000.[6] However, many models of commercial tillage equipment sold on the market today are equipped with a seed drill option. A survey of existing equipment would be necessary to estimate the total likely aggregate capital costs of Ohio farmers moving completely toward no-till farming.

Bio Fuels

The market cost of price of corn ethanol is very dependent on corn prices. Ethanol costs an estimated $1.40 per gallon at $2.34 per bushel of corn. The cost increases to $1.79 per gallon at $4.62 per bushel.[7] Historically, corn prices range between $1.50 to nearly $3 per bushel.[8]

The future cost/profitability of cellulosic ethanol will remain highly speculative until the process is closer to commercialization. An early estimate is $1.54 per gallon, assuming a cost of $50 per ton for corn stover feed stock and $0.041 per kilowatt hour (kwh) for co-generated electricity from the ethanol facility.[9]

Bio Power

The cost of retrofitting pulverized coal plants with the equipment necessary to co-fire biomass ranges from an estimated $150 to $300 per kwh. Cyclone boilers offer the lowest cost opportunities, estimated as low as $50 per kwh.[10]

Fuel supply is the most important cost factor. Key issues for fuel cost are primarily dependability and proximity. Ohio could supply an estimated 19 million dry tons of biomass at $50 per ton.[11]

MEASURING SUCCESS

Carbon Budget Impacts

Near-term Carbon Budget Savings[12]

Bio fuels and conservation tillage are technologies commercially used today and can provide immediate emissions reduction benefits.

Long-term Carbon Budget Management[13]

Transportation sector: Bio fuels could provide up to 9% of the total budget cut needed for the transportation sector.

Power production sector: Bio products (in conjunction with geologic sequestration) could provide up to 30% of total budget cuts needed for the power production sector.

Specific Greenhouse Gas Reduction Examples[14]

Applying conservation tillage practices and maintaining the current rate of forest carbon sequestration would provide an annual estimated reduction of 39,687,278 tons of CO_2 (9.84 MMTC) through 2030. For the purposes of this analysis, it is estimated that agricultural soil carbon will be saturated after 2030. No assumptions are made about forest carbon.

Replacing 10% of petroleum fuel for light duty vehicles with bio fuels such as cellulosic ethanol, or conventional ethanol produced from low/no carbon electricity sources, would reduce annual estimated tailpipe greenhouse gas emissions by 5,081,076 tons of CO_2 (1.26 MMTC) in the year 2010.

Using a 15% biomass mix in coal gasification plants that are sequestering carbon could reduce annual estimated greenhouse gas emissions from coal plants by 461,143 tons of CO_2 (0.11 MMTC) in 2015 and up to 22,352,867 tons of CO_2 (5.54 MMTC) by 2045.

ADVANCED COAL GENERATION AND CARBON SEQUESTRATION

Ohio should move aggressively to promote the development of coal gasification and carbon sequestration. Efforts should focus on promoting utility base load power facilities as well as coal to fuels and other processes. Steps should also be taken to develop the tools and experience necessary to widely deploy carbon sequestration technology. Advanced fossil technologies can take Ohio 64% of the way to where we need to be with respect to annual CO_2 emissions by mid century.

Technology Options

Advanced Fossil Generation

Coal Gasification

Currently, the most promising technology to reduce greenhouse gas emissions from coal-based electric power is through coal gasification. Coal gasification is a process where coal is heated under pressure and becomes a synthetic gas or “syn gas” composed of primarily hydrogen and carbon monoxide (CO). This gas can then be burned in a gas turbine (like a natural gas-fired power plant) for electricity. This gas also can be used for making other “co-products” such as methane, chemical feed stocks, hydrogen, and fuel.

Because it is a low volume gas, it is relatively inexpensive to virtually eliminate nearly all health-damaging air pollutants such as mercury and sulfur. Carbon dioxide also can be captured in a relatively cost effective manner (compared with other technologies) by injecting oxygen into the synthetic gas (which converts the CO to CO_2) and removing the CO_2 through a technology known as an amine process. Once captured, the CO_2 can be compressed and injected into deep geologic formations for potentially permanent storage.

Examples of these pollution controls in commercial applications include the Eastman coal gasifier in Kingsport, Tennessee. This facility manufacturers chemical feed stocks from coal and removes 99.9% of both the mercury and sulfur pollutants in order to maintain product purity. The Dakota Gasification Company in Beulah, North Dakota manufactures methane from coal for residential and commercial heating. The CO_2 from the plant is captured and sent over a hundred miles by pipeline to aging oil fields in Saskatchewan. It is injected into the oil fields where it enhances oil production and becomes geologically sequestered.

It is important to note that absent carbon capture and sequestration technology, the CO_2 emissions profile for gasification is mixed. Integrated Gasification Combined Cycle (IGCC) is roughly 20% more efficient than conventional existing coal plants and therefore will have lower emissions. On the other hand, diesel fuel derived from coal will generate 1.8 times more CO_2 emissions due to the higher carbon content of coal relative to petroleum and natural gas. It is also important to note that the CO_2 capture process is more cost effective for the coal to fuel and natural gas facilities than for IGCC facilities.

Oxy Blown Super Critical Pulverized Coal-fired Power Plants

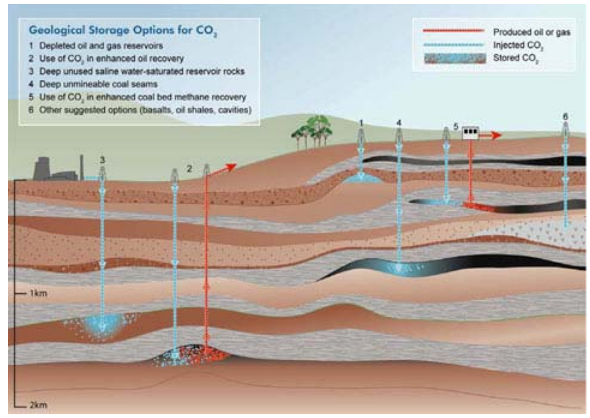
Oxy blown super critical coal-fired power plants are similar to conventional pulverized coal-fired power plants, except they use pure oxygen instead of air in the combustion process. This means that the flue gas of the facility is mostly made up of carbon dioxide, which makes extracting CO_2 much less expensive than it would be from conventional pulverized coal flue gas. Once the CO_2 is captured using an amine process, the CO_2 can be compressed and injected into deep geologic formations for potentially permanent storage.

Electro Catalytic Oxidation

Electro catalytic oxidation (ECO) is a pollution control technology for conventional power plants that is being developed by First Energy and Powerspan. It is technically capable of capturing CO_2. The conventional control aspect of the technology will be undergoing a demonstration-scale project at First Energy's Bay Shore plant in Oregon, Ohio. However, the cost and feasibility of the CO_2 capture technology is as of yet undetermined.

Algae Controls

Researchers at Ohio University are looking at directing carbon dioxide into algae ponds that, through photosynthesis, create biomass as an end product.



Carbon Sequestration

Carbon Capture

Carbon dioxide capture is the separation of CO_2 from emissions sources and the recovery of a concentrated stream of CO_2 that is amenable to sequestration or conversion. The CO_2 is first captured through a chemical absorbent. Once captured, the CO_2 is cycled out of the gas stream or flue and then released into a compressor which pressurizes the gas in preparation for geologic sequestration.

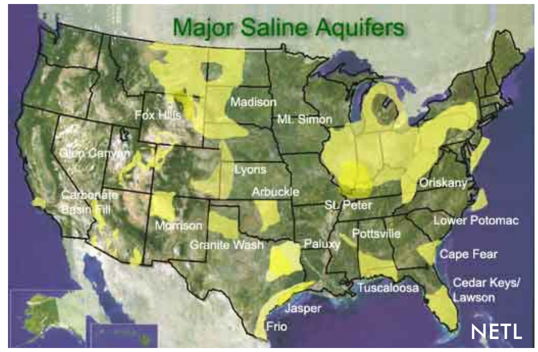
Sequestration in Geologic Formations

Carbon dioxide is sequestered, or held in place, in geologic formations when the gas is pumped into layers of porous rock deep underground that are "capped" by a layer of non-porous rock above them. The CO_2 is buoyant and flows upward until it encounters the layer of non-porous rock and becomes trapped. Over time, the CO_2 can dissolve in liquids, react with minerals to form solid carbonates, or adsorb onto porous surfaces of rock. Once in place, the CO_2 can be potentially trapped for hundreds of thousands of years, or longer.[15]

Ohio has an abundance of geologic formations in which CO_2 can be sequestered. The types of geologic formations available in Ohio include:

- Oil and gas reservoirs–Carbon dioxide can be trapped below the non-porous cap rock of oil and gas reservoirs. In addition, the CO_2 injected into an oil reservoir can enable incremental oil recovery. Carbon dioxide enhanced oil recovery (EOR) is a commercial process, mostly used by large oil companies with major oil fields. Often these companies will drill to find CO_2 stored underground and transmit the CO_2 by pipeline to a large oil field for EOR. In this way, EOR can provide revenue to the supplier of CO_2, while generating a net reduction of greenhouse gases.[16] Ohio oil and gas producers have, by and large, never attempted to utilize large EOR projects in part because Ohio's oil producers are relatively smaller operations.
- Unmineable coal beds–Methane is adsorbed onto porous surfaces of coal. However, coal prefers CO_2 and will replace methane with CO_2 upon exposure. Coal beds that are unmineable because they are too deep or too thin to be mined economically are possible candidates for geologic sequestration. Carbon dioxide can be pumped into the unmineable coal seams which will push out the methane. The methane can then be captured and used for power and heat. Like depleting oil reservoirs, unmineable coal beds offer an opportunity to generate revenue for CO_2 and create a net reduction of greenhouse gases.[17]

- Deep saline formations–Deep saline formations are layers of porous rock that are saturated with brine. In addition to having a non-porous cap rock, saline formations contain minerals that could react with injected CO_2 to form solid carbonates. Overall, the potential for deep saline formations to store CO_2 is many times that of coal and oil and will likely provide the space needed for carbon sequestration over the long-term. However, saline formations do not produce a revenue stream as do oil and gas fields or unmineable coal.[18]



Carbon Materials and Products

Possible future methods of sequestering CO_2 include turning the carbon from carbon dioxide into an inert solid material and, in some cases, a potentially commercial product.

- Carbon nano fibers–One of the most interesting potential approaches to using carbon from fossil fuels is the production of carbon nano fibers. The carbon from gasified coal can be turned into carbon nano fibers. This product has a very wide variety of uses including ultra-durable concrete, very light yet strong vehicles, highly conductive transmission wires, and nanotechnology applications. Applied Science Inc. of Willoughby, Ohio is a pioneer in this area of research. Initial research by the MIT Laboratory for Energy and the Environment indicates that while there are engineering challenges to integrating this technology with current gasification technology, this path may be more economical than carbon sequestration on a cost basis alone (not including potential revenue).[19]
- Mineral sequestration–Researchers at the Los Alamos National Laboratory are looking into sequestering carbon through the creation of mineral carbonates from carbon dioxide and magnesium rich ore. However, unlike carbon nano fibers, this does not appear to provide an added commercial value.

FOUNDATION FOR ACTION

In April 2006, the Public Utilities Commission of Ohio approved American Electric Power's (AEP) general plan to develop a 600 megawatt coal gasification power plant in Meigs County. The PUCO will review full design costs, construction costs, and specific rate recovery plans in a future case.

Currently in Ohio there are three other potential coal gasification facilities being considered in Ohio–a combination IGCC and synthetic natural gas plant in Allen County by Global Energy/Lima Energy, a coal to fuels facility in Lawrence County by Baard Energy, and a coal to fuels facility in Scioto County by CME North American Merchant Energy.

The Ohio Air Quality Development Authority, the Ohio Coal Development Office, and the Ohio Department of Natural Resources are participating in the Midwest Regional Carbon Sequestration Project (MRCSP)–a program sponsored by the U.S. Department of Energy that is focused on moving the research and development of carbon sequestration forward through small initial test projects in the region. The Ohio Environmental Council supports this objective and is a partner in the project.

The Ohio FutureGen Task Force is an initiative to build the world's first integrated sequestration and hydrogen production research power plant. The Ohio FutureGen Task Force is working to secure this $1 billion power generation laboratory/facility in Ohio. Developing this project in Ohio will advance our experience and understanding of sequestering carbon dioxide from the power sector. The Ohio Environmental Council supports this objective and is an active member of the Task Force.

In order to support Ohio's bid for the FutureGen project, the Ohio General Assembly has approved funding for a $2 million deep strategic test well drilling project to help develop data for evaluating carbon sequestration opportunities.

Recommended Measures

Promoting Advanced Coal Gasification

Front End Engineering Design Package Cost Offset

The Front End Engineering Design (FEED) package is the upfront cost to private developers for the initial engineering of a facility. Ohio should consider adopting a FEED package cost offset program that allows developers to recoup their initial engineering costs through state tax credits that are applicable during the first ten years of the life of the facility, up to the full amount of the FEED package. While the total amount of the FEED package cost is relatively small, it provides an important incentive for independent project developers who often use their own resources to develop the initial facility. In Illinois, the FEED package tax incentive is credited for helping to spur significant interest in gasification project development in Illinois. FEED packages can cost roughly $10 million for a utility-scale gasification facility.

Investment or Production Tax Credit

An investment or production tax credit would allow a project developer to recoup some of the total amount invested in developing a facility through a credit on future taxes. The State of Indiana adopted a “Coal Gasification Technology Investment Tax Credit”. Under this program, the amount of the state tax credit would be equal to 10% of the first $500 million invested in a qualifying IGCC facility and 5% of any investment above that amount. The credit will apply to newly constructed IGCC facilities in Indiana that use 100% Indiana coal. The credit went into effect January 1, 2006. Ohio should consider developing a similar program for the current restructured electric utility environment. The investment tax credit program for the state of Indiana would allow a credit of $75 million for a $1 billion investment in a coal gasification power facility. The total costs apply to a potential loss of future tax revenue.

Three-Party Covenant

To the extent that Ohio adopts some form of re-regulation for electric utilities, it should consider developing a Three-Party Covenant program to help stimulate the construction of IGCC power plants. The Three-Party Covenant works by structuring a financial arrangement between the federal government, state public utilities commission, and equity investors. Under the Three-Party Covenant, the federal government provides credit, the state public utilities commission provides an assured revenue stream to protect the federal credit, and the developer provides equity and initiative to build an IGCC project. In return, the federal government stimulates IGCC deployment to support energy and environmental policy objectives at low federal cost, the state receives competitively priced power, economic development benefits (investment and jobs), and environmental improvement, and the equity investor receives access to non-recourse, low-cost debt, assured equity returns, and an economic base-load power plant.

As an example, the State of Indiana adopted a law that specifically directed its Public Service Commission to provide rate recovery and “in construction” recovery for new gasification projects that use Indiana coal.

At the federal level, the 2005 federal energy bill created a program that provided loan guarantees for new gasification facilities. However, Congress has not yet appropriated the funds that would be necessary to implement the program.

Next Steps for Promoting Advanced Coal Gasification

1. Government agencies, NGOs, trade associations and developers should work together to identify how limited FEED package incentive programs could be developed from existing administrative funding sources such as the Ohio Coal Development Office, the Ohio Energy Loan Fund, or the Third Frontier program.
2. Lawmakers should consider adopting the 2005 rider for the Energy Loan Fund on a permanent basis to fund a targeted grants program to develop advanced technology energy sources, such as advanced fossil fuels.
3. Lawmakers, NGOs, trade associations, utilities and developers should explore the viability of larger investment and production tax credits–specifically the financial affordability for the state and effectiveness in moving base-load power projects forward under the current regulatory restructured electric utility environment.
4. If the Ohio General Assembly is considering reinstating some form of rate-payer recovery, it should consider including a provision allowing a limited number of IGCCs that could recover "in-construction costs". Limitations could be based on whether or not a threshold number of base-load IGCC projects (five, for example) have been initiated in the United States.

Developing Carbon Sequestration

Geologic Assessment

In order to prepare for the major activity necessary to develop large-scale geologic sequestration in Ohio, we need a much better assessment of geologic storage potential and potential rates for CO_2 diffusion (i.e. how much CO_2 can be stored annually). A significant first step toward this would be a project to analyze the characteristics of the extensive library of core samples housed in the Ohio Geologic Survey's Sample Repository, operated by the Ohio DNR Division of Geological Survey, and a program to evaluate sequestration potential of specific geology using existing injection wells. This effort would be highly complementary to the test drilling efforts under Ohio's bid for FutureGen and the pilot sequestration projects occurring under the MRCSP. These projects can then be integrated with existing and developing data to properly characterize and map Ohio's sequestration potential in proper detail. It would also help lay groundwork for potential enhanced oil and gas recovery/sequestration projects.

Enhanced Oil/Gas Recovery (EOR/EGR) Project Development Assistance

For Great Lakes area states (Illinois, Indiana, Ohio, Michigan and Pennsylvania), there are many small oil and gas producers who have not traditionally used EOR/EGR, in part, because they are not individually large enough to develop a cost-effective project. In addition, there will likely be technical issues unique to this region's geology that will need to be addressed. State governments, companies, trade associations, and NGO's can potentially play a useful role in helping to identify the specific solutions to potential technical and market challenges which area producers may face with respect to establishing a cost-effective EOR/EGR sequestration program in Ohio. Key issues that would likely be considered include, but are not limited to, market structure, local geology, removing excess CO_2 from product, CO_2 pipeline siting, well capping, and monitoring.

Advanced Energy Portfolio Standard

Twenty three states have adopted a renewable energy portfolio standard, where power suppliers are required to obtain a portion of their power from renewable energy sources. Pennsylvania adopted a variation on that policy that may be most applicable to Ohio, known as a "technology portfolio standard". In Pennsylvania, power providers can choose among several options to meet a cleaner power requirement, including renewable energy, energy efficiency, and even coal waste. If geologic carbon sequestration were also included, this would further promote the development of coal gasification or oxy blown coal technology.

Development of Geologic Sequestration Regulatory Process

In order to set the stage for geologic sequestration projects to move forward in a five to ten year time frame, it will be important to ensure that the necessary regulatory apparatus is developed. State regulatory agencies (Ohio EPA, PUCO, and Ohio DNR's Division of Mineral Resources Management) should begin to develop the necessary permit processes that will be needed for geologic sequestration, including permit guidelines for pipelines, drilling, storage, and monitoring.

Tax Incentives or Loan Programs for EOR/EGR from Gasification Project's Carbon Dioxide Streams

Tax incentives to oil producers for EOR projects may be useful in stimulating interest. Incentives could be limited to CO_2 streams from power generation or gasification projects. No- or low-interest loan programs may also be a viable option to assist operators with the large up-front costs of developing these projects.

Developing Workforce "Infrastructure" for Gasification and Carbon Sequestration Industries

States and regions should consider updating their workforce training and research and development investments, with a focus on developing the gasification and carbon sequestration industries.

Next Steps for Developing Carbon Sequestration

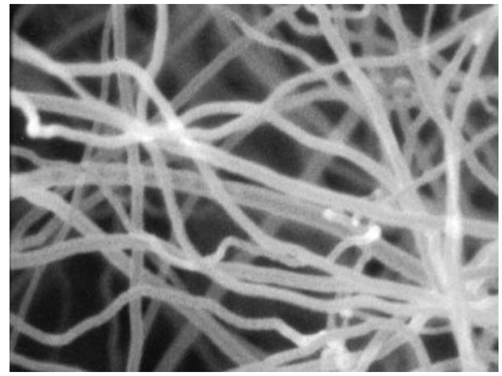
1. The Ohio DNR Division of Geologic Survey, with input from stakeholders, should develop a comprehensive geologic sequestration assessment strategy. Priority assessments should be immediately funded by the General Assembly, and a multi-year funding strategy should be developed for the remaining assessment needs.
2. Once proper assessments are available, the Ohio Power Siting Board should develop siting criteria for large carbon dioxide-emitting plants that include provisions for sequestration.
3. Oil and gas producers, gasification developers, NGOs and state agencies should identify technical and market barriers and solutions to promote EOR/EGR.
4. NGOs and businesses interested in developing clean energy markets should develop legislation to promote minimum use standards for advanced technology power production. These stakeholders should work with the Ohio General Assembly to adopt these recommendations into law.
5. The Ohio EPA and the Ohio DNR Division of Mineral Resources Management should develop an interagency task force to develop permitting guidance for EOR, EGR, coal bed methane recovery and saline aquifer sequestration.
6. Oil and gas producers, gasification developers, NGOs and state agencies should explore the development of tax credits and other financial incentives necessary to foster EOR/EGR.
7. The Ohio Third Frontier Project should consider focusing on investing in workforce training issues related to the gasification industry and should encourage turbine industry focus on compression technology development.

Co-Benefits from Moving to Advanced Coal and Carbon Sequestration Technology

Coal gasification offers substantial environmental improvements over conventional coal burning technology, including:

- Improved reduction of air pollutants such as sulfur dioxide, nitrogen oxide and mercury. Nitrogen oxide can be reduced by 98%, sulfur dioxide by 99.9%, and mercury by 99.9%. The emissions from a fully controlled coal gasification plant are very similar to that of a natural gas plant. In addition, the costs of the pollution controls are substantially less expensive than that of conventional coal plants.

- Wastes from coal gasification facilities are about half the volume of those from fully controlled conventional coal plants.
- The water usage of coal gasification facilities is significantly less than that of conventional coal facilities.
- In addition to electricity, coal gasification can produce vehicle fuels, chemical feed stock for the polymer industry and, possibly in the future, advanced materials such as carbon nano fibers.
- Carbon dioxide can be used for enhanced oil and gas recovery from depleted primary oil wells and for recovery of methane located in unmineable coal seams.
- "Coal to fuels" can promote domestic energy/energy security.



Costs

Coal Gasification Versus Conventional Coal Fired Power

Coal facilities are billion dollar-scale projects. A useful way to understand the costs of advanced fossil fuel is to compare the cost of a new conventional pulverized coal plant to the cost of a new Integrated Gasification Combined Cycle plant. According to the Electric Power Research Institute, the cost of electricity from a new typical conventional coal plant is estimated at $0.0466 per kilowatt hour and the cost from a new IGCC plant is estimated at $0.0483 per kilowatt hour.[20] It should be noted that industry experts expect a reduction in IGCC costs as the first several utility-scale commercial plants are built. In addition, the economics shift significantly in favor of IGCC with the addition of carbon sequestration.

Carbon Capture and Sequestration

Estimates by the U.S. Department of Energy (DOE) indicate that total carbon capture and compression adds 18% to the cost of coal gasification power and 89% to the cost of conventional pulverized coal plants. The U.S. DOE has set a goal of lowering capture and compression costs to no more than 10% additional to the total generation costs of a power plant by 2020.[21]

MEASURING SUCCESS

Carbon Budget Impacts

Near-term Carbon Budget Savings[22]

Coal gasification and carbon sequestration are long-term capital and time intensive projects that would not likely start to provide any significant reduction benefits for at least 10 to 15 years.

Long-term Carbon Budget Management[23]

Power production sector: Coal gasification and carbon sequestration could supply 115% of the needed carbon budget cuts for the electric power sector, exceeding the target reduction goal of 65% to 95%.

Thermal sector (heating and industrial processes): Coal gasification with carbon sequestration applied to industrial heat generation would supply 21% of the budgets cuts needed for the thermal sector.

Specific Greenhouse Gas Reduction Examples[24]

Replacing Ohio's current conventional coal power plants over a 30 year period (starting in 2015) with advanced coal generation and carbon sequestration would reduce annual emissions of CO_2 by an estimated 104,513,427 tons (25.91 MMTC by 2045) from year 2000 emission levels.

ELECTRIC AND HEATING EFFICIENCY

Promoting more efficient use of energy in Ohio is a clear win both economically and in terms of reducing greenhouse gas emissions. Energy efficiency is as much an on-going process as a product. As long as new products and technology improvements are possible, the ability to invest in efficiency will be available. The ideal outcome of any energy efficiency policy is to incorporate the on-going process of using energy more efficiently in product design, building design, and consumer choices. Investing in efficiency for electricity and natural gas can take Ohio 43% of the way to where we need to be with respect to annual CO_2 emissions by mid century.

Technology Options

Reducing Electricity and Heat Demand

Products

Improving the efficiency of appliances, electronics, heating and cooling systems, and lighting are all opportunities to reduce the use of electricity and natural gas. The two primary efficiency standards that products have to meet are the mandatory federal and state appliance standards and the voluntary Energy Star® standards set by the U.S. EPA.

Building Design and Maintenance

The design and maintenance of a building can significantly impact its energy use. A building's use of light and passive solar energy for heat, its insulation, and the design of its heating and cooling systems can all reduce electricity and natural gas usage. There are continual improvements in building technologies that can improve efficiency, including framing and roofing materials and advanced sensors and controls.

An important concept for energy efficiency in buildings is the building envelope, which is everything that separates the interior of the building from the outdoor environment: doors, windows, walls, foundation, roof, and insulation. Heating and cooling systems typically use the most energy in houses and buildings. In houses, programmable thermostats and zone heating and cooling systems, which reduce heating and cooling in unused areas, are important energy savings strategies. In commercial buildings, integrated space and water heating systems are an important energy saving strategy. Once the systems are in place, their proper operation and maintenance is critical to efficient energy use.

Industrial Process Efficiency

Creating industrial products can be extremely energy intensive and, in many situations, industrial process energy use can be significantly reduced by improving the efficiency of equipment such as motors, variable speed drives and compressed air systems. Optimizing industrial process system energy use can, in many cases, save large amounts of energy.

Motors, power pumps, fans and blowers, air compressors and dozens of other mechanical devices are used in nearly all types of industrial production. Some specific examples of industrial efficiency improvements include:

- In the chemical industry, the use of catalysts that lower the energy requirements for chemical reactions and computer programs that model chemical behavior.
- In the glass industry, the use of pure oxygen-fueled furnaces that burn at higher temperatures and new heat-resistant materials.

Efficient Fuel Use

Combined Heat and Power

Combined heat and power (CHP) is the generation of heat and power in a single process. A combustion boiler burns fossil fuel or biomass to drive electrical generators which generate electricity and heat that can be used for industrial processes and heating.

The combination of utilizing of heat from electricity generation and avoiding transmission losses because electricity is generated on-site means that CHP typically achieves a 35% reduction in primary energy usage compared to power stations and heat-only boilers. Currently, commercially common CHP installations achieve a reduction of over 30% in CO_2 emissions in comparison to generation from coal-fired power stations and over 10% reduction in comparison to gas-fired combined cycle gas turbines. The newest state of the art installations can achieve a reduction of over 50% compared to generation from coal-fired power stations.[25]

FOUNDATION FOR ACTION

The Public Utilities Commission of Ohio is considering a proposed program by Duke Energy (formerly Cinergy) that would invest $8 million annually into demand side management for both electricity and natural gas.

The Ohio Energy Loan Fund is a loan fund established to provide an incentive for Ohioans to start energy efficiency and renewable energy projects. It reduces the interest rate on standard bank loans for those qualifying Ohio residents and businesses that borrow money to implement an energy efficiency or renewable energy project.

Ohio is the home of manufacturers of energy efficient products such as insulation by Owens-Corning and energy efficient washers by Whirlpool.

As of April, 2006, the Ohio House of Representatives has adopted House Bill 251 (Uecker). House Bill 251 would extend current state facility planning requirements to any state agency or institution and also to any public school. Specifically the bill would:

- Require the Department of Administrative Services (DAS) to develop efficiency standards for state-funded facilities (excluding higher education) and require the facilities to be managed by state-certified operators.
- Require the Office of Energy Efficiency (OEE) to provide technical assistance for state purchasing.
- Require that competitive bids to the state include whether the product or service meet federal green building guidelines and require a preference for that choice.
- Provide for the creation of an interuniversity committee to develop building efficiency guidelines for state institutions of higher education and a 15-year plan for reducing on- and off-campus building energy expenditures by at least 20% by 2014.
- Require each higher education boards of trustees to adopt rules that carry out those campus energy guidelines.

The OEC supports and has provided technical comments on the legislation.

Recommended Measures

Combined Heat and Power Program

Ohio has a significant opportunity to reduce greenhouse gas emissions and help Ohio businesses, particularly manufacturing facilities, reduce their energy costs by promoting combined heat and power. In addition, as with other distributed generation types of facilities, CHP can help promote the integrity of the electric grid. Ohio must address the following three areas to promote the broad use of CHP:

- Allowing greater access to financing
- Promoting small- and mid-sized project development
- Creating a transparent and standardized process for grid interconnection

Three immediate steps that will help address these issues include:

- Greater utilization of the Ohio Energy Loan Fund for CHP–While the Ohio Energy Loan Fund is potentially accessible for CHP projects, it is significantly underutilized for this purpose compared to its potential. The Ohio Office of Energy Efficiency should work with potential customers and developers to create a streamlined, user-friendly program to specifically promote the development of CHP.
- Small- and mid-sized project market development–The Ohio Department of Development, large industrial trade associations, and other customer representatives should develop a program to help educate potential mid-sized customers about the opportunity for CHP. In addition, the stakeholders should explore the development of a small- and mid-sized customer “purchasing pool” that could help leverage more market offerings from developers for those project sizes.

- Transparent, standardized interconnection–Currently, Ohio interconnection rules are based on the Institute of Electrical and Electronics Engineers (IEEE) grid interconnection standards (series 1547). However, the Commission has provided electric utilities with considerable latitude and do not currently have any mechanism for tracking interconnection activity. The PUCO should develop a system that provides transparent tracking of how electric transmission and distribution companies apply those standards for each interconnection. Specific issues that are tracked should include, but not be limited to, size of generation facility, generation type (fuel, etc.), type of contract (net metering, etc.), and how utility discretion is applied.

Large customers, such as CHP customers, that are contemplating a self-generation project should consider setting up a contract under Ohio’s net metering provision. This may allow for interconnection at the distribution rather than the transmission level.

Demand Side Management

Demand side management (DSM) is a program that helps reduce the need for additional base load electricity generation by reducing the growth in demand for electricity. This can be accomplished in several ways, but the primary focus of DSM is usually to provide incentives for electricity customers to use more energy efficient products and to focus their electricity usage toward non-peak usage times. In the year 2004, 14,000 megawatts of peak load electricity reduction in the U.S. was met through demand side management programs.[26]

Ohio should develop a DSM program that is able to function in the current electric utility restructured environment or in a "re-regulated" environment and subject to rigorous accounting in order to track the effectiveness of the program.

To more accurately understand the energy savings potential for Ohio, an in depth study should be commissioned by the State of Ohio. The recent efficiency potential study for the State of Wisconsin by the Energy Center of Wisconsin would be a useful example to potentially follow.[27]

There are two examples of strategies that Ohio could consider for a program that would function under various regulatory scenarios and that could lend itself to accurate tracking of effectiveness.

Developing an Energy Efficiency Resource Standard

An Energy Efficiency Resource Standard (EERS) consists of electric and/or gas energy savings targets for utilities, with the flexibility to achieve the targets through a market-based trading system. These targets could be met through end-user energy-saving improvements, distribution system efficiency improvements, combined heat and power systems, and other high-efficiency distributed generation systems. As with other portfolio standards, the trading provision allows a utility that saves more than its target to sell savings credits to utilities that fall short of their savings targets, permitting the market to produce the lowest-cost savings.

When the State of Texas restructured its electric utility system, it established a requirement that utilities offset 10% of their demand growth through end use efficiency. Since 2001, the utilities in Texas have been meeting this target with relative ease and have been exceeding the targets starting in 2003. Other states that have similar programs include Nevada, Hawaii, Connecticut, and California. Illinois and New Jersey are in the process of developing EERS programs.[28]

Independent DSM Programs

Traditionally, DSM programs have been managed by utilities. Some states have developed DSM programs that operate as independent organizations.

In Wisconsin, Focus on Energy is a public-private partnership offering energy information and services to residential, business, and industrial customers throughout Wisconsin. These services are delivered by a group of firms contracted by the Wisconsin Department of Administration's Division of Energy cash back rewards program. A recent study by the Energy Center of Wisconsin indicates that the program is capable of reducing between 0.5% and 0.7% of annual statewide electricity use for an investment of $71 to $121 million annually.

Efficiency Vermont is Vermont's "Energy Efficiency Utility" which operates independently of investor-owned electric utility companies. Efficiency Vermont reports that its energy efficiency programs resulted in energy savings of 20,142 megawatt hours (MWh) and peak load reductions of 2.2 MW at a cost of $5.4 million in 2000. Of these energy savings, 47% were in the residential sector, approximately 30% were in the commercial sector and the remaining 23% were in the industrial sector.

Building Standards

The state of Ohio should adopt a program to promote the use of green building designs and systems for state government and universities in Ohio *(see the section on House Bill 251 in Foundation for Action for more information)*. Local governments should follow suit with similar efforts.

State Appliance Standards

Appliance and equipment efficiency standards have been one of the most successful policies used by state governments and the federal government to save energy. These standards prohibit the production and import or sale of appliances and other energy-consuming products that are less efficient than the minimum state or federal efficiency requirements.

In the United States, minimum-efficiency standards for appliances and other equipment were initiated at the state level first (California, Florida, Kansas, Massachusetts, and New York) starting in the 1970's. Congress adopted federal standards in 1987. These initial efficiency standards focused on the "low-hanging fruit" such as major residential appliances (e.g., refrigerators, air conditioners, water heaters, washers and dryers, etc.) as well as the most common commercial equipment (e.g., fluorescent lamps, motors, furnaces, etc.) More recently, state programs have expanded to include products that have new, more efficient options–such as cable boxes, ice makers and others.

Federal standards have continued to lag behind state standards. Currently nine states (Arizona, California, Connecticut, Maryland, New Jersey, New York, Oregon, Rhode Island, and Washington) have adopted efficiency standards for appliances and equipment not covered at the federal level.

According to estimates by the Appliance Standards Awareness project, Ohio energy customers could save an estimated $307 million annually on energy bills by adopting appliance standards not covered at the federal level.[29]

Next Steps for Promoting Electric and Heating Efficiency

1. The Ohio Office of Energy Efficiency should set up a working group with representatives of CHP project developers and customers to identify the best methods of using the Energy Loan Fund to promote CHP projects.
2. Lawmakers should ensure the Ohio Energy Loan Fund is fully capitalized by extending the 2005 level rider to make up for any previous transfers of the fund to other programs. Lawmakers should also consider maintaining the rider on a permanent basis to fund a targeted grants program to develop advanced technology energy sources.
3. Lawmakers, NGO's, and utilities should evaluate possible designs for a DSM effort in Ohio, looking to Texas and Wisconsin as examples.
4. The Ohio Office of Energy Efficiency should develop an advisory committee and put out a request for proposal for a comprehensive analysis on the energy efficiency potential in Ohio.
5. The Ohio General Assembly should move quickly to adopt a state buildings efficiency program (such as House Bill 251).
6. The PUCO should initiate a rule making procedure to develop a tracking system of interconnection projects to better understand market activity and development opportunities.
7. Lawmakers should consider passing appliance standards legislation modeled after laws in Arizona, Maryland and other states.

Co-Benefits from Promoting Energy Efficiency

Energy efficiency provides substantial savings for energy customers of all classes. According to a recent study by the Energy Center of Wisconsin, a five year investment in energy efficiency would produce up to 2,000 jobs over that time period in that state, due to local investment from customer savings.[30]

Greater management of electricity load growth helps reduce additional strains on the electricity grid.

By promoting the on-going process of efficiency, Ohio is promoting the development of new technologies and products.

Most of the growth in the natural gas supply is occurring through imported liquefied natural gas. Promoting efficiency in gas use will help reduce the demand for non-domestic fuel supplies.

Costs

One metric that is helpful in understanding efficiency costs is estimating how much electricity is saved per total investment. For example, in year 2000, Ohio's residential, commercial, and industrial customers consumed 161,264,609 MWh of electricity.[31] Investing 2.7 mils ($0.0027) per kWh, or $435,306,444, in a demand side efficiency program would have saved an estimated 1,612,528 MWh of electricity–shaving about 1% from Ohio's electricity demand.[32] For a typical household that used 800 kWh of electricity per month, that would translate to an additional $2.10 per month on their electric bill.

In 2000, the average price for electricity was $0.0617 per kilowatt hour.[33] Therefore, an efficiency investment of this magnitude would have created an annual savings of $99,492,977. Assuming the investments continue to provide comparable savings over the following four years, the total savings over that time would amount to $497,464,885. In other words, the investment was recouped, or paid back, in a five year period *(see the section on Demand Side Management in Recommended Measures for suggestions regarding a robust analysis of this opportunity)*.

MEASURING SUCCESS

Carbon Budget Impacts

Near-term Carbon Budget Savings[34]

Electric and heating efficiency can and does provide immediate reductions in greenhouse gas emissions.

Long-term Carbon Budget Management[35]

Power production sector: Long-term application of electric efficiency would supply up to 63% of the total carbon budget cut needed for the power production sector.

Thermal sector (heating and industrial processes): Long-term application of heating efficiency would supply up to 11.5% of the total carbon budget cut needed for the thermal sector.

Specific Greenhouse Gas Reduction Examples[36]

Based on the target of reducing electricity use by 1% per year from business as usual emissions (which are currently growing about 2% per year), the total annual reduction potential from demand reduction efforts provides a small estimated reduction initially of 8,469,846 tons of CO_2 (2.1 MMTC) in 2010 from business as usual emissions, but ramps up over time to an estimated 25,127,209 tons of CO_2 by 2020 (6.23 MMTC) and continues to grow each year.

If Ohio utilized its technical capacity potential of combined heat and power of 10,000 megawatts by 2020, that would produce an annual reduction of 11,960,008 tons of CO_2 (2.96 MMTC from year 2000 levels).

Ohio could reduce 2,371,566 tons of CO_2 (0.588 MMTC) annually by adopting appliance standards not covered at the federal level.[37]

METHANE

Ohio should focus on significantly reducing its methane emissions. Methane is a very potent greenhouse gas–twenty-three times stronger than CO_2. In addition, reducing methane can be one of the most inexpensive, and in some cases profitable, methods of cutting greenhouse gas emissions. Using commercial technologies and practices could reduce methane emissions from Ohio by 70% over the next 20 years and maintain low levels of emissions going forward.

Technology Options

Landfill Methane Recovery

Landfill methane comes from the anaerobic decomposition of biomass from municipal waste. This methane can be captured and burned, which converts the methane to CO_2. Since methane is 23 times more potent as a greenhouse gas, this process significantly reduces the global warming impact from landfill methane emissions.

All new landfills, and some existing ones, must meet U.S. EPA's new source performance standards for controlling methane emissions from landfills. This requires landfills to use a system to collect and burn methane and other gas emissions from the landfills.

In Ohio, most landfills have closed and are no longer accepting waste. Consequently, their waste will stop emitting methane within 25 years. However, the 23% of existing landfills in Ohio which remain open account for 76% of the sector's emissions. All new landfills must meet federal standards for control equipment.[38] The U.S. EPA estimates that the landfill controls only capture and burn about 60% of the methane, allowing the remaining 40% to vent to the atmosphere.[39]

There are technologies that can add value to the methane capture process and make capturing up to 90% of the emissions profitable. These include capturing the landfill gas to burn as fuel for generating electricity and converting the methane to vehicle fuel.

Animal Feedlot Lagoons and Biodigesters

Liquid manure management systems, such as ponds, anaerobic lagoons, and holding tanks, are the primary source of methane from animal waste management. Manure deposited on fields and pastures, or otherwise handled in dry form, produces insignificant amounts of methane.

The primary biogas recovery system that is currently commercially available is a biodigester system. A biodigester generates and captures the methane created from the anaerobic digestion of manure. The gas can then be used for heating and electricity generation and the waste can be used as dry fertilizer. Compared to a traditional slurry-filled lagoon waste management system, a biodigester can virtually eliminate feedlot methane emissions.[40] This also has significant benefits in terms of odor and ammonia management.

Cattle and Feed Efficiency

Direct methane emissions from cattle account for 69,555 tons of methane (0.44 MMTCE). Changes in feed formulation and processing could reduce dairy cattle emissions by 30% and beef cattle emissions by 20%.[41]

Cattle emit methane through a digestive process that is unique to ruminant animals (cows and buffalo, for example) called enteric fermentation. Efforts to reduce emissions from beef cattle have been focused on areas such as better grazing management and dietary supplementation. These areas are the most effective ways to improve efficiency and reduce emissions, because they improve animal nutrition and reproductive efficiency. More successful pregnancies in cattle lead to the need for less breeding cattle; thus, a smaller cattle population and lower emissions. Efforts to improve emissions from dairy cattle have been focused on reducing the methane generating properties of feed. In many cases, improving efficiency can reduce emissions and help the farm operation's profitability.

Near-term opportunities for feed modification to reduce methane emissions include changing the composition of feed, adding nutritional supplements, and greater precision for feed quantities. Longer-term opportunities for feed modification include anti- and pro-biotic alternatives, altering cellulose properties in the feed, creating biochemical inhibitors for methane production, and breeding more efficient livestock.

Coal Mine Methane Recovery

Coal bed methane is methane contained in coal seams and is often referred to as virgin coal bed methane or coal seam gas. Coal mine methane is the subset of coal bed methane that is released from the coal seams during the process of coal mining.

Methane is typically removed from gassy underground coal mines by large ventilation fans. The methane mixes with the ventilation air and is carried out of the mine through the exhaust system. Emerging technology can be installed in mines with ventilation air methane concentrations that are too low for methane removal that can oxidize the ventilation air methane to CO_2 and thus reduce its global warming potential by 98%.[42]

Increasingly though, mine ventilation is supplemented by a degasification system that removes methane in advance of mining, during mining activities, or after mining has occurred. The methane that is removed in advance of mining often is very high quality and acceptable for injection into natural gas pipelines. Methane that is removed after the coal is mined comes from the "gob," or debris that fills the empty space once an empty coal seam collapses, and can be of high quality, but often will require gas clean up.[43] Coal seam "de-gassing" ahead of mining operations typically can economically capture a very large fraction of coal seam methane content and result in much greater recovery and much lower mining operations release of methane. Early technology would capture only 60% of the gas over a 20 year period. The recent Pinnacle Project in West Virginia by CDX on behalf of U.S. Steel demonstrated a significant advancement in degasification that allows for up to 90% gas capture in a two to three year period.[44] In addition to producing pipeline quality gas, the captured methane also can be turned into a fuel for electricity generation or vehicle use.

Both the degasification processes and advanced ventilation air methane systems are extremely efficient at utilizing the methane, and can significantly reduce or virtually eliminate methane emissions.[45]

Natural Gas Infrastructure Maintenance and Upgrades

Natural gas pipelines, wells, and processing facilities emit 228,960 tons of methane annually in Ohio (1.44 MMTCE). Methane can leak from these systems even when they are properly managed. Leakage can be highest at points where natural gas transmission systems connect with distribution systems (city gates) or other large point users of natural gas (like power plants). Such leakage can be reduced through investment in appropriate engineering measures.[46]

Examples of technologies that can reduce emissions include:

- Replacing high bleed pneumatics with low bleed systems (86% reduction)
- Compressor station leak inspection and maintenance (13% reduction)
- Fuel gas retrofit for blow-down valves (33% reduction)
- Composite wrap repairs (100% reduction)

Estimates from U.S. EPA's Natural Gas STAR program indicate that emissions from pipelines and processing facilities can be reduced by up to 50% with improved maintenance and upgrades. In many cases, these practices can lead to savings for the gas processors and transmission and distribution companies.

Municipal Wastewater Methane Recovery

Methane from municipal wastewater can be reduced either by providing adequate exposure to aerobic environments, such as aeration and aerobic micro-organisms, or by using anaerobic digesters like those described for use in animal feedlots. As with the animal feedlot technology, methane emissions can be virtually eliminated.

FOUNDATION FOR ACTION

Over 32 megawatts of landfill methane power generation have been sited in Ohio to date.

Two of Ohio's major natural gas distribution companies, Columbia and Cinergy, participate in U.S. EPA's voluntary Natural Gas STAR program which focuses on methane leakage prevention from pipeline and processing infrastructure.

Recommended Measures

Waste Methane Production Tax Credit

One of the beneficial uses of methane emissions is as a fuel for generating electricity. A production tax credit provides companies that generate electricity a credit on their corporate franchise tax on a per kilowatt hour basis. For example, this program would provide a $0.004 tax credit for every kilowatt hour of electricity that a company generates from methane that is captured from landfills, coal mines, animal feedlots, or municipal waste treatment systems. A similar tax credit could be developed on a per cubic foot basis for waste methane used for heating, industrial, or vehicle fuel purposes.

Best Management Practices for Pipelines, Storage and Processing

All of Ohio's gas producers, processors, distribution companies, and transmission companies should participate in the U.S. EPA's voluntary Natural Gas STAR Program. Current program participation in Ohio includes the BP gas processing facility in Cleveland and the Columbia and Cinergy distribution companies. However, Vectren, East Ohio Gas, Dominion, Arlington Natural Gas and several other smaller distribution systems are not participating in the program. Nationally, the U.S. EPA Natural Gas STAR program reported a 25 billion cubic foot emissions reduction in 2003.

State Government Procurement Requirement of Methane Power and Fuel

The State of Ohio should adopt a procurement policy that requires state government to purchase at least 10% of its energy from cleaner energy resources, including methane from agricultural, coal, and municipal waste sources. In Pennsylvania, the State purchases 100,000 megawatt-hours (about 10% of its total need) from renewable energy sources and waste coal. Thirty five percent is required to be purchased from wind power and 10% from burning waste coal in circulating fluidized bed facilities, at a premium of 0.34 cents per kilowatt hour.

The State of Ohio purchases 120,000 MWh of electricity each year. Estimates by developers indicate that there is at least 250 MW of landfill methane power available in Ohio, more than enough to meet the entire load required by the State.

Advanced Technology Portfolio Standard

Twenty-three states have adopted a renewable portfolio standard, where power suppliers are required to obtain a portion of their power from renewable energy sources. Pennsylvania adopted a variation on that policy that may be most applicable to Ohio, known as a "technology portfolio standard". In the Pennsylvania case, power providers have several options to meet a cleaner power requirement, including renewable energy, energy efficiency, and even coal waste.

With the relatively low cost of converting methane to power, even a modest technology portfolio standard that includes methane would likely result in many sources developing waste to power projects.

Promoting Feed Efficiency

There are near-term steps that cattle operations can take to improve feed and livestock production efficiency that will also reduce methane emissions. Most efforts to improve feed efficiency focus on reducing feed intake and feed costs. Usually a side benefit of increasing feed efficiency is producing less methane.

The Ohio Department of Agriculture and the Ohio State University Agricultural Extension Program should work with cattle operations to implement the following actions:

- Develop a methane emissions baseline and monitoring operation using the Livestock Analysis Model and the sulfur hexafluoride monitoring technique.
- U.S. EPA's Air Emissions Consent Agreements with swine, poultry and dairy farmers will result in air quality measurements of criteria pollutants. Participants and agency staff should explore the opportunity for voluntary add-on measurements of methane.
- Provide operators with the latest information available on near-term opportunities to improve efficiency and reduce methane emissions.
- Develop a set of procedures that allow operators to register reductions with a voluntary state registry.
- Ensure that extension programs and other educational resources are providing the most up to date information on feed efficiency improvement research.

Promoting Transparent, Standardized Grid Interconnection

Currently, Ohio interconnection rules are based on the Institute of Electrical and Electronics Engineers (IEEE) grid interconnection standards (series 1547). However, the Commission has provided electric utilities with considerable latitude and do not currently have any mechanism for tracking interconnection activity. The PUCO should develop a system that provides transparent tracking of how electric transmissions and distribution companies apply those standards for each interconnection. Specific issues that are tracked should include, but not be limited to size of generation facility, generation type (fuel, etc.), type of contract (net metering, etc), and how utility discretion is applied.

Larger customers contemplating a self-generation project should consider setting up a contract under Ohio's net metering provision. This may allow for interconnection at the distribution rather than the transmission level.

Next Steps for Reducing Methane

1. Stakeholders including NGO's, trade associations, and lawmakers should work together to develop a legislative proposal that would create a tax credit for waste methane power and fuel from sources including landfills, feedlots, coal mines, and municipal sewer systems.
2. More Ohio companies should join U.S. EPA's voluntary Natural Gas STAR program. The Ohio EPA should work with these companies to develop baseline inventories for methane emissions and then provide an opportunity for documented reductions to be used in a greenhouse gas registry.
3. NGO's and businesses interested in developing clean energy markets should develop legislation to promote minimum use standards for advanced technology power production. House Bill 247 (Skindell), which calls for a renewable portfolio standard of 20% by 2021, is a good place to start, but should be modified to have more of a focus on greenhouse gas emissions reduction, including the geologic sequestration of carbon. These stakeholders should work with the Ohio General Assembly to adopt these recommendations into law.
4. The Ohio Department of Agriculture and the Ohio State University Agricultural Extension Program should develop a joint outreach and education effort to cattle operations on methane reduction opportunities.
5. In order to facilitate the sale of greenhouse gas credits for methane reduction, the State of Ohio should develop a voluntary registry program and a state greenhouse gas credit aggregator program *(see section on Building Greenhouse Gas Markets)*.
6. The PUCO should initiate a rule making procedure to develop a tracking system of interconnection projects to better understand market activity and development opportunities.

Co-Benefits from Reducing Methane

Some technologies can add economic value–both to agribusiness and to the public (such as distributed generation of electricity which improves electric grid reliability).

Businesses or facilities located near these sources could utilize their energy and have a hedge against high or volatile natural gas prices.

Methane emission reduction from animal feedlots and landfills will help with problems such as black fly infestations and odors for homes and businesses located near the facilities.

Manure lagoons from feedlots, a significant source of methane, also pose water quality challenges. Technologies such as bio digesters eliminate the need for lagoons and reduce emissions by more than 90%.

Reducing methane globally will reduce ground level ozone–benefiting public health and our climate.

Costs

For projects that can convert methane to a product, such as electricity generation and pipeline gas, a useful metric to understand cost is the "break even point"–the point for which the financial return on a project offsets the cost. The U.S. Department of Energy estimates that natural gas prices will range between roughly $5.00 and $6.00 per million BTU for the foreseeable future. Many methane reduction projects can break even at natural gas price levels that are at or below that range.[47]

For landfill methane power projects, capital costs can range from $1 million to $7 million, depending on project size. However, power generation projects for most landfills in Ohio will be profitable (well above the break even point) with a natural gas market rate of $4.67 per million BTU or a wholesale electricity market rate of $0.042 per kWh.[48]

For animal feedlots, the costs vary considerably according to animal type, digester type, and size of operation. For example, the capital cost for a lagoon digester for dairy cattle can range between $245 and $380 per cow. A mix digester for swine can cost between $130 and $200 per hog. An example of a break even point would be a dairy cattle operation with 700 dairy cows. The capital cost of the project would be $188,000 with annual revenue of $34,000 (assuming the farmer is paid $0.02 per kWh for electricity generated by the facility).[49]

For coal bed methane recovery, degasification systems have a break even point range of a gas price range of $2.34 to $5.79 per million BTU, depending on the difficulty of the operation. Using catalytic oxidation systems with existing underground mine operations in Ohio would cost roughly $30.00 per metric ton of carbon equivalent, or roughly $11 million annually.[50]

For the natural gas transmission and distribution system, a 30% reduction in system emissions is cost effective at a gas price of $2.43 per million BTU. For a gas price of $6.00 per million BTU, emissions reductions of up to 40% are cost effective. Up to 50% emissions reductions can be achieved cost effectively at a gas price of $12.00 per million BTU.[51]

There currently are no well-established cost estimates for methane reduction options with respect to enteric fermentation.

MEASURING SUCCESS

ìQuick and Cheap Coolingî from Other Emission Reductions [52]

A key issue with respect to methane is that the reductions are relatively inexpensive, and the cooling benefits occur within 10 years, rather than over a century or more. In order to maximize the ability to stabilize climate emissions, nations with developed economies and states like Ohio should focus on reducing their methane emissions from a year 2000 baseline by at least 70%.

Specific Greenhouse Gas Reduction Examples[53]

For Ohio, a 70% reduction would be equivalent to reducing 14,439,071 tons of CO_2 (3.58 MMTCE) or 627,785 tons of methane. Specific paths to meet this reduction goal include:

A combination of attrition for older landfills and maximizing methane capture ability for newer landfills would result in Ohio reducing up to 90% of annual landfill methane emissions by 2030 (from a year 2000 baseline)–this would mean an estimated reduction of 385,866 tons of methane (2.21 MMTCE).

Biodigesters can virtually eliminate methane emissions from feedlot operations. Applying them to all of Ohio's feedlots would result in an annual estimated reduction of 22,698 tons of methane (0.13 MMTCE) from year 2000 levels.

Changes in cattle feed and processing could reduce methane emissions from cattle in Ohio by 26% (no time estimate available) from year 2000 levels. This would produce an estimated reduction of 19,206 tons of methane (0.11 MMTCE).

A combination of coal mine degasification and ventilation air methane combustion can reduce annual Ohio coal mine methane emissions by more than 90%–an estimated reduction of 61,110 tons of methane (0.35 MMTCE) from year 2000 emissions on an annual basis.

As with biodigesters for feedlots, wastewater methane emissions in Ohio can be virtually eliminated from year 2000 levels–an estimated reduction of 24,444 tons of methane (0.14 MMTCE).

Proper maintenance and certain upgrades to the natural gas production, transmission and distribution infrastructure can reduce emissions up to 50%–an estimated annual reduction in Ohio of 2,903,947 tons of CO_2 (0.72 MMTCE).

VEHICLE EFFICIENCY

Vehicle efficiency is one of the most easily developed greenhouse gas reduction strategies for the transportation sector. It is particularly helpful because it has the ability to help leverage relatively large greenhouse gas reductions. Focusing on vehicle efficiency is imperative because the transition to a low- or no-carbon fuel, such as hydrogen, appears to be the most difficult for the transportation sector. Improved vehicle efficiency can take Ohio 21% of the way to where we need to be with respect to annual CO_2 emissions by mid century.

Technology Options

Conventional Technology Improvements

There are several opportunities for conventional improvements in light duty vehicles with respect to engines, transmissions, aerodynamics and tire drag, and inertia losses. Several studies suggest that a 20% to 25% reduction in greenhouse gas emissions is possible by adopting existing technology improvements.[54]

Electric Hybrid Drivetrains

An electric hybrid vehicle uses energy from braking to supply energy to the battery system. With some systems, such as the technology used by the Toyota Prius, the vehicle uses the battery for power at lower speeds and the gasoline engine at higher speeds. For other systems, such as the Honda Insight, the battery is used to assist the gasoline engine with power at both lower and higher speeds. The engine-battery technology of electric hybrids in combination with conventional technology improvements can provide a total greenhouse gas reduction of 40% to 50%. While electric hybrid drivetrains have been applied to larger vehicles such as buses and utility vehicles, current technology is generally not well suited for vehicles that carry very heavy loads, tow other equipment, or primarily are used for high-speed highway travel.[55]

Hydraulic Hybrid Drivetrains

Rather than using a battery to store power, hydraulic hybrid drivetrains use regenerative braking to capture and recover energy in the form of pressurized hydraulic fluid. This technology has been developed primarily for larger vehicles that carry heavy loads and also experience frequent starts and stops. Eaton and Peterbuilt recently have announced one of the first hydraulic hybrid vehicles–a trash hauler with this system that is estimated by the manufacturer to be 25% to 30% more fuel efficient than a conventional hauler.[56]. The U.S. EPA has been working with Eaton to develop this technology for medium-sized trucks and is targeting a fuel efficiency increase of between 60% and 70%.[57]

Plug-in Hybrid Electric Vehicles

Plug-in Hybrid Electric Vehicles (PHEVs) are grid-connectable hybrid electric vehicles that can operate on conventional gasoline or diesel and potentially on biofuels. The CO_2 emissions of PHEVs potentially are 50% lower than a gasoline electric hybrid, on a tailpipe basis.[58] However, total CO_2 emissions from vehicle use are highly dependent on the electricity source for the battery re-charging. Daimler Chrysler currently is testing a PHEV minivan, known as the Sprint.

Homogeneous Combustion Compression Ignition

Many heavy duty vehicles probably will need to utilize advanced combustion systems like Homogeneous Combustion Compression Ignition (HCCI) to meet future emission standards. If HCCI can successfully be commercialized, diesel engines in combination with other conventional technology improvements (like those previously mentioned) could provide greenhouse gas reductions for heavy duty vehicles of up to 35%. These engines also are well suited to lighter duty gasoline load carrying vehicles like pickup trucks, cargo vans and large SUVs.[59] Caterpillar's new ACERT engine is the first commercial application of this technology in a heavy duty engine.

FOUNDATION FOR ACTION

Ohio has a long-standing history of auto manufacturing–one of Ohio's largest manufacturing employers. Honda, for instance, is a major manufacturer of hybrid electric vehicles and is one of the largest manufacturing employers in the state.

Cleveland-based Eaton Corporation (one of the world's most diversified industrial manufacturers) developed a diesel electric hybrid utility vehicle for FedEx that is 50% more fuel efficient than the conventional FedEx vehicle. This hybrid model is slated to become the replacement vehicle for future FedEx delivery vehicles.

Both Eaton and Parker Hannifin (one of the world's leading manufacturers of motion and control technologies and systems, headquartered in Cleveland) have developed a hydraulic hybrid drivetrain for heavy duty vehicles.

Ohio House Bill 453 (Mason) would establish a state tax credit for new hybrid vehicle purchases. Under the proposed legislation, hybrid vehicles achieving 40 miles per gallon (mpg) or better according to U.S. EPA estimates would receive a $3,000 tax credit. Hybrid vehicles achieving less than 40 mpg would receive a $2,000 tax credit.

Recommended Measures

Within every class of vehicle, there is at least a 25% difference between the most efficient and least efficient vehicles. Ohio should focus on implementing measures that promote the development and use of the most efficient vehicle for each type.

Sales Tax Incentives

Ohio should consider adopting a sales tax credit for fuel efficient vehicles. Currently, ten states (Colorado, Connecticut, Florida, Maine, New Jersey, New York, Oregon, Pennsylvania, Utah and Washington) have tax incentives for the purchase of electric hybrid vehicles or fuel efficient vehicles. Most states focus the tax credits on the technology use, although Connecticut and Washington have a 40 mpg and 50 mpg minimum requirement, respectively. In order to maximize the greenhouse gas reduction benefit, one potential approach would be to apply a tax credit to the most efficient vehicles for each vehicle class.

Government Procurement

The State of Ohio vehicle fleets should meet a minimum high efficiency standard for new vehicle purchases, as well as meet an overall fleet efficiency target *(see Ohio House Bill 245 in Bio Sequestration and Products section for example approach)*.

Multi-state Cooperation

The FedEx/Eaton partnership led to the development of a new, much more fuel-efficient vehicle because of FedEx's vision and purchasing power. The State of Ohio should reach out to other states to consider creating a larger purchasing pool that can work with vehicle developers and manufacturers to produce more efficient vehicle types that meet state government needs. Manufacturers require an annual vehicle market size of approximately 25,000 new vehicle purchases before they are willing to introduce a new vehicle model to the marketplace. Ohio's state fleet is comprised of 7,100 vehicles. That number may not be enough to meet a manufacturer's new vehicle production requirement, but collectively the total estimated size of vehicle fleets from all states is 525,000 vehicles.

Voluntary Upgrades of Private Fleet Vehicles

Private fleet vehicles should consider developing voluntary new vehicle purchasing guidelines based on efficiency and adopt a total fleet efficiency target. While the FedEx/Eaton partnership resulted in the development of an entirely new vehicle, many companies with private vehicle fleets can upgrade their light and heavy duty vehicle fleets with vehicles and technologies that currently are available.

Community Hybrid Plug-in Programs

Vehicle manufacturers and utilities should work with a local community to "road test" how plug-in hybrids could be integrated into local transportation needs. A variety of local private and public fleets could be utilized to explore the more immediate practical niches for using this technology.

Next Steps for Vehicle Efficiency

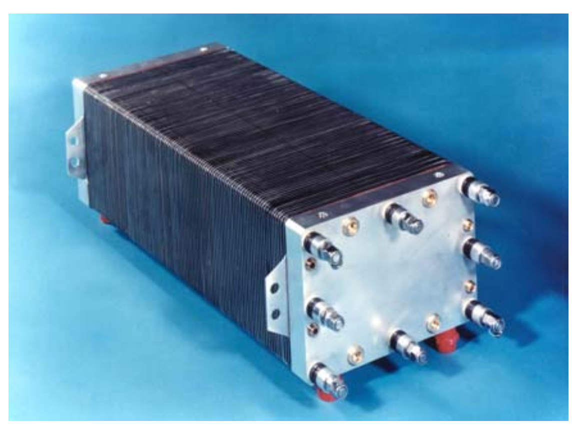
1. NGOs, business interests, and other stakeholders should work with the Department of Administrative Services to develop state procurement guidelines for efficient vehicles.
2. NGOs, business interests, and other stakeholders should work with state lawmakers to develop and adopt a sales tax incentive program targeted at the most efficient vehicles in all vehicle classes *(see Ohio House Bill 453 in Foundation for Action for more information)*.
3. The Governor should reach out to other Midwest/Great Lakes Governors to test interest in developing a larger purchasing pool that can drive vehicle efficiency improvements.
4. NGOs and private fleet owners should develop pilot programs to encourage private sector investment in more efficient vehicles.
5. The Governor should develop a working group to identify key research, development, and deployment projects for the next generation of energy markets, such as those mentioned above. The projects potentially could be leveraged through state activities, such as the Third Frontier Initiative and the Ohio FutureGen Task Force.

Co-Benefits from Promoting Vehicle Efficiency

Reducing petroleum consumption will help improve our energy security.

Ohio is historically a major manufacturer in the auto industry. Promoting innovative technology advancements will play to Ohio's strengths in manufacturing.

The state of Ohio is working to lay the foundation for our state role as a major manufacturer in the fuel cell industry. Development of efficient electric hybrid drivetrains is an important step toward developing fuel cell vehicles.



Costs

Conventional Technology Improvements

Studies suggest that a 20% to 25% reduction in greenhouse gas emissions is possible for a retail price impact of roughly $1,500.[60]

Hybrid Electric Vehicle (HEV)

The retail price impact of an HEV is on the order of $4,000, but could come down in the future to about $2,500.[61]

Plug-in Hybrid Electric Vehicle (PHEV)

Initial industry cost estimates are that PHEVs will cost an additional 10% to 20% above conventional hybrid electric vehicles.[62]

Homogeneous Combustion Compression Ignition (HCCI)

HCCI could provide greenhouse gas reductions of 30% to 35% for a cost of about $3,500 per engine.[63]

MEASURING SUCCESS

Carbon Budget Impacts

Near-term Carbon Budget Savings[64]

Utilizing more efficient vehicles provides immediate benefits for reducing carbon dioxide.

Long-term Carbon Budget Management[65]

Vehicle sector: Development and deployment of more efficient vehicles could supply an estimated 57.5% of the total budget cut needed for the transportation sector.

Specific Greenhouse Gas Reduction Examples[66]

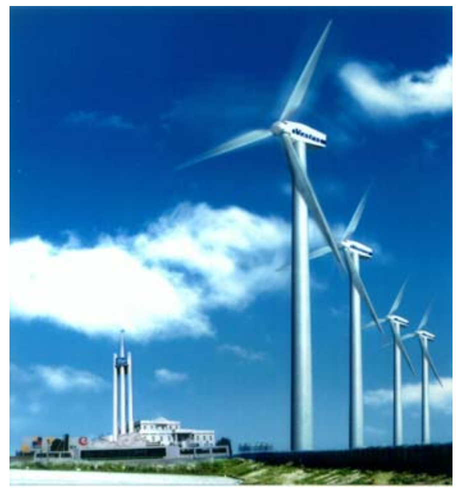
Gradually improving vehicle efficiency in light and heavy duty vehicles could reduce estimated annual tail pipe greenhouse gas emissions by as much as 43% by mid century–an annual estimated reduction of 56,365,282 tons of CO_2 (13.98 MMTC).

WIND AND SOLAR

While the ultimate focus of reducing greenhouse gas emissions is on deep, long-term, reductions, it is equally important to begin to reduce emissions in the near-term. Wind and solar energy can play a significant role in reducing greenhouse gas emissions in Ohio because of the ability to deploy these technologies immediately. However, they may also offer long-term benefits for deep reductions in our state, depending on future technology development. Investing in current commercial wind and solar technologies can take Ohio 7% of the way to where we need to be with respect to annual CO_2 emissions by mid century.

Technology Options

Wind Power



Wind is one of the few power technologies that is commercially available today and produces virtually no greenhouse gases as a byproduct of power production.

Ohio has been the center of innovation for many of the major developments in wind technology. The first large windmill to generate electricity was built in Cleveland, Ohio, in 1888 by Charles F. Brush. The machine had multiple blades and was more than 50 feet in diameter. In the 1970s, NASA's Lewis Research Center in Cleveland developed the first modern two-blade wind turbine for electric power production. Modern commercial turbines are direct descendants of the NASA turbine developed in the 1970s.

Today, a single wind turbine can produce up to 1.8 MW of electricity, although turbines that generate more power are in development. In most cases, several turbines are grouped together to form "wind farms". Wind farms in the U.S. today range from roughly 5 MW to 600 MW in size.[67]

Wind power tends to be less efficient than the traditional base load power in that it operates at about 30% of its capacity on average, due to the intermittent nature of wind.

According to the analysis "Repowering the Midwest" by the Environmental Law and Policy Center of the Midwest, Ohio has the potential for approximately 920 MW of wind power.[68] A recent analysis conducted for the Ohio Department of Development indicates that this is likely a conservative estimate.[69]

Technology Advancements

Most of the technology advancements for wind power are focused on making turbines lighter and capturing more of the energy for electricity production. Examples of specific efforts include lighter and more efficient drive trains, increasing energy capture through wider diameter rotors, and two-blade rotor designs.[70]

Hybrid Wind

- Wind air compression–One possible hybrid technology for wind is using wind turbines to directly compress air into storage tanks and then releasing the compressed air for power generation during times when demand for electricity is greatest. By dispatching wind generated electricity during peak demand times, this technology could potentially improve its economic viability in areas where the wind is marginal.[71]
- Wind/Bio fuels–Another potential method of improving the ability to dispatch power from a "wind farm" is the possibility of combining wind turbines with diesel generator sets that run on bio fuels, such as bio diesel or bio oil. Potentially combining these technologies may have the ability to improve the capacity factor of stand-alone wind turbines from roughly 30% up to 65% during the warmer seasons. Rural areas are often considered for the siting of wind turbines. The use of bio fuels in combination with wind is another potentially important synergy between wind and agriculture.[72]

Photovoltaic Power (Solar)

Solar electricity systems, or photovoltaic (PV) cells, are electricity-producing devices made of semiconductor materials. These PV cells typically are connected together to form PV modules that may be up to several feet long and wide that, in turn, can be combined into arrays.

The current generation of PV technology, referred to as Generation I, is a direct descendent of space exploration in the 1960's and 70's. Today's solar panels are 20% efficient at producing electricity. Generation I global solar production has grown from 10 MW of production in 1980 to 1,200 MW production in 2004. The various markets for solar panels are: countries and states that provide a significant subsidy for solar electricity (e.g. Germany, Japan, California, New York); communities in developing countries that don't have an established electricity grid; companies and individuals that are willing to pay extra to have a portion of their electricity supplied by solar power; and profitable niche markets–such as road signs and street lights.[73]

The next generation of solar technology is already seeing some commercial activity. Generation II, or thin film solar technology, is projected to be much less expensive than current solar technology ($0.075 cents per kWh), but with similar efficiencies and life spans. Daystar is a New York-based company that is manufacturing this type of solar technology for smaller applications including blankets, bags, tents, etc.–although the cost and efficiency has not met projected estimates for the technology.[74]

Generation III solar will require significant improvements in efficiency–up to the 65% level. Meeting this efficiency goal will require advanced research in using organic molecules and carbon nanofibers in the PV process.[75]

FOUNDATION FOR ACTION

The Bowling Green Municipal Utility has developed the first utility scale (4MW) wind power production facility in Ohio.

Ohio is second in the nation for companies that are in the wind turbine manufacturing supply chain, including Parker Hannifin, Owens Corning, and Timken Steel.

One of the largest solar panel manufacturers in the nation, First Solar, is located in Perrysburg, Ohio.

First Energy recently announced an agreement with a wind power company to purchase power from a future 250 MW wind farm in West Virginia over a 20 year period.

Ohio House Bill 247 (Skindell) calls for a Renewable Portfolio Standard of 20% by 2021. OEC supports this legislation.

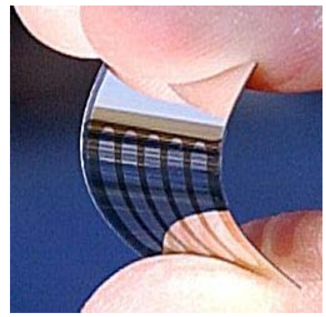
Computer modeling of Ohio's wind power potential, commissioned by the Ohio Department of Development, identified several possible areas with commercially viable wind speeds (class IV) on land in Ohio and just off-shore in Lake Erie (class IV and V).

Recommended Measures

Advanced Technology Portfolio Standard

Twenty-three states have adopted a Renewable Portfolio Standard, where electric power suppliers are required to produce and/or obtain a portion of their power from renewable energy sources. Pennsylvania adopted a variation of that policy, known as a Technology Portfolio Standard. Under Pennsylvania law, electric power providers have several options to meet the law's cleaner power requirement, including renewable energy, energy efficiency, and coal waste. This option may be most applicable to any effort in Ohio that focuses on broadly addressing greenhouse gas emissions (*see sections on Advanced Coal and Carbon Sequestration, Methane, and Bio Sequestration and Products*).

Commercializing New Technologies



As noted above, there are several important potential new developments in wind and solar technologies. One challenge facing any technology is the "valley of death" of commercialization. The term refers to the difficulty in obtaining funding or financing to move from the research and development stage to the fully commercial stage. Smaller innovators typically don't have the necessary capital and larger firms are often risk averse to investing in new product development outside their core business. In addition to the early design engineering incentives suggested in the *Advanced Coal and Carbon Sequestration* and *Bio Sequestration and Products* sections, Ohio should consider directing money from the Ohio Third Frontier Project to focus on the commercialization challenge facing new energy and climate friendly technologies.

Targeted Grants Program

The Ohio Energy Loan Fund grants program provides financial support for distributed generation projects, including photovoltaic projects. Given the limited funding available under the program, the Ohio Department of Development should consider developing "performance standards" for PV systems for which the Department of Development is willing to provide grant funding. For example, projects that are utilizing technologies with more promising efficiency or cost profiles should receive a preference. Setting such standards also would help educate end users and leverage them as a stronger force in product innovation.

Power Production Tax Credit

Ohio should consider adopting a production tax credit for wind power. This tax credit applied at the federal level has been one of the most successful renewable energy incentive programs developed to date.

State Government Procurement

The State of Ohio should adopt a procurement policy that requires state government to purchase at least 10% of its energy from cleaner energy resources, including methane from agricultural, coal, and municipal waste sources. In Pennsylvania, the state government purchases 100,000 MWh (about 10% of its total annual demand) from renewable energy sources and waste coal. By Pennsylvania law, 35% of the 100,000 MWh is required to be purchased from wind power and 10% from burning waste coal in circulating fluidized bed facilities. The coal waste fetches a premium of $0.34 cents per kWh.

Promoting Transparent, Standardized Grid Interconnection

Currently, Ohio interconnection rules are based on the Institute of Electrical and Electronics Engineers (IEEE) grid interconnection standards (series 1547). However, the Commission has provided electric utilities with considerable latitude and do not currently have any mechanism for tracking interconnection activity. The PUCO should develop a system that provides transparent tracking of how electric transmissions and distribution companies apply those standards for each interconnection. Specific issues that are tracked should include, but not be limited to size of generation facility, generation type (fuel, etc.), type of contract (net metering, etc.), and how utility discretion is applied.

Larger customers contemplating a self-generation project should consider setting up a contract under Ohio's net metering provision. This may allow for interconnection at the distribution rather than the transmission level.

Next Steps for Promoting Wind and Solar

1. NGO's and businesses interested in developing clean energy markets should champion legislation to promote minimum use standards for advanced technology power production (*see Ohio House Bill 247 in Foundation for Action*). Stakeholders should work with the Ohio General Assembly to adopt these recommendations into law.
2. The Ohio Third Frontier Project board should work with NGO's, trade associations, economic development agencies, and the general assembly to develop more flexibility within the program to target commercial demonstration opportunities for new energy and climate friendly technologies.
3. The Ohio Department of Development should develop a set of performance standards for grants to photovoltaic installations using the technology vision outlined by the U.S. DOE's National Renewable Energy Laboratory as a frame of reference.
4. Lawmakers also should consider making permanent the 2005 rider for the Energy Loan Fund to fund a more targeted grants program to develop advanced technology energy sources.
5. NGOs, trade associations, and lawmakers should develop legislation to adopt a production tax credit in Ohio for wind power.
6. The PUCO should initiate a rule making procedure to develop a tracking system of interconnection projects to better understand market activity and development opportunities.

Co-Benefits

As mentioned above, Ohio businesses already have a stake in the renewable energy industry. Encouraging additional development of this industry, both in terms of stimulating demand and investing in innovation, will help this industry grow further.

Wind and solar are more distributed generation technologies. As such, these energy sources help promote reliability in the electricity grid.

Costs

A useful metric for understanding wind power costs are to compare them to wholesale electricity costs. Current wholesale electricity costs in Ohio average $0.035 to $0.04 per kWh. Current wind power technology best competes commercially (without any tax incentives) in areas where the wind is both strong and consistent. In other areas, such as where the wind is more marginal (less consistently strong), wind power has relied on a federal production tax credit of $0.015 per kWh to maintain commercial viability. The U.S. Department of Energy is working with private sector companies to develop wind turbines that generate electricity in more marginal wind areas at a cost of $0.03 to $0.04 per kWh.[76]

In many cases, solar power will offset electricity that is needed for homes and businesses, rather than act as a generation technology that supplies power to the electricity grid. So a useful metric to understand the cost of solar technology is to compare it to retail electric rates. In Ohio, the average retail rate for electricity is $0.845 per kWh for residential customers, $0.0775 per kWh for commercial customers, and $0.0489 per kWh for industrial customers. Today's solar panels cost about $0.30 cents per kWh, averaged over the 30 year lifespan of the panel. Generation II, or thin film solar technology, is projected to be much less expensive than current solar technology ($0.075 cents per kWh). The U.S. Department of Energy has targeted Generation III solar technology, using carbon nanofibers and other advanced materials, for a generation cost of $0.04 cents per kWh.[77]

MEASURING SUCCESS

Carbon Budget Impacts

Near-Term Carbon Budget Savings[78]

Wind and solar provide immediate carbon dioxide reduction benefits. Both are commercially available and easily deployable.

Long-Term Carbon Budget Management[79]

Power production sector: Current commercial wind and solar power would only meet an estimated two percent of the electric power production sector's carbon budget—not a significant portion of the carbon cuts needed to meet this sector's carbon budget. Potential technology advancements that change the economics of these technologies could significantly improve their long-term effectiveness.

Specific Greenhouse Gas Reduction Examples[80]

If wind power grew from today's 4 MW to 920 MW in Ohio by the year 2020, it would result in an estimated annual reduction of 17,139,374 tons of CO_2 (4.54 MMTC).

It is unlikely that the current generation of solar technology will be deployed at a level that will significantly reduce greenhouse gas emissions in the near-term. However, the next generation solar technology—thin film—which is becoming commercial, may have a much greater potential to impact greenhouse gas emissions. Solar technology is much more likely to function like energy efficiency than base-load power generation. Generation II and III solar technologies may play an important role in meeting energy efficiency goals such as reducing electricity demand of base-load power by 1% per year from current business-as-usual power demand projections (demand currently is growing at about 2% per year). As noted in the *Electricity and Heating Efficiency* section, the total annual reduction potential from demand reduction efforts provides a small reduction initially of an estimated 8,469,846 tons of CO_2 (2.1 MMTC) in 2010, but ramps up over time to an estimated 25,127,209 tons of CO_2 by 2020 (6.23 MMTC) and continues to grow each year.

BUILDING GREENHOUSE GAS MARKETS

Ohio sources of greenhouse gas emissions should reduce their emissions by participating in a greenhouse gas market. A greenhouse gas market is the buying or selling of credits that represent the reduction or offset of greenhouse gases. Emissions trading—such as for acid rain credits—is a proven market-based system that provides companies with the flexibility to meet their environmental goals at lowest cost while reducing emissions. The State of Ohio should adopt programs and promote actions that would help establish a viable greenhouse gas market. The private sector in Ohio should consider participating in voluntary market programs. It is impossible to tell which technologies would be most utilized in order to meet emission reduction targets under a greenhouse gas market structure, but the use of markets is likely to drive the most cost effective choices.

Market Mechanisms

Greenhouse Gas Credit Trading

One of the most cost efficient processes for reducing greenhouse gas emissions is a market for trading of greenhouse gas emissions credits. A credit represents an amount of emissions (e.g., one ton of CO_2) that has been successfully reduced. A broad greenhouse gas credit trading system can drive diverse reductions in all emission categories.

In a greenhouse gas credit trading system, all participants establish a baseline of greenhouse gas emission levels (typically their own emission level during a previous period of time), and then reduce their emissions by a fixed amount over time (e.g., 1% per year). Every year, participants individually find the most cost-effective way to meet their target. They earn a credit for every ton of emissions reduction that exceeds their annual target, and can trade (sell) the credit to another participant who has fallen short of its target. In this way participants are given flexibility to determine what reductions work best for them, and they receive (or pay) a market-based financial incentive depending on their success in meeting the targets. The end result is that participants will use a combination of the following strategies:

- investing in technology that will reduce emissions, and/or
- purchasing credits, and in effect investing in technology, from other participants that have exceeded their reduction goals.

A credit trading program can be voluntary, such as the Chicago Climate Exchange (CCX). This market exchange, based in Chicago, creates a marketplace where voluntary credit buyers, such as American Electric Power, can purchase greenhouse gas emission reduction credits from sellers, such as the Iowa Farm Bureau.

Initial greenhouse gas emissions reduction targets for CCX participants are 1% per year for a four year period, starting in 2003. Tradable credits are based on emission reductions for carbon dioxide, methane, nitrous oxide (N_2O), fluorocarbons (PFCs, HFCs) and sulfur hexaflouide (SF_6). In addition to direct “in house” reductions in greenhouse gas emissions, qualifying reduction projects currently include renewable energy, energy efficiency improvements, soil carbon sink expansion or protection, waste methane recovery and fuel efficiency improvements for vehicle fleets.

Mandatory programs require emitters in a certain geographic region to reduce their emissions either directly or by purchasing credits. These programs can exist at a state, regional, national, or international level. In the Regional Greenhouse Gas Initiative (RGGI), several states in the Northeast have developed a mandatory greenhouse gas emissions reduction requirement for electric power generators, but allow the trading of credits throughout the region as a means of meeting the requirement. In addition, the initiative will allow some offsets to be purchased outside the region from states like Ohio.

Examples of proposed national mandatory credit trading programs include the proposed McCain-Lieberman bill, and the targets endorsed by the National Committee on Energy Policy. Currently, the only international mandatory agreement on greenhouse gases is the Kyoto Protocol.

Greenhouse Gas Registry

A helpful step in developing either a voluntary or mandatory market is the creation of a registry for sources in order to verify their reductions of greenhouse gas emissions or their sequestration of carbon dioxide. Registries can be helpful in facilitating a voluntary program by assuring the buyers of emissions credits that their purchase is certified. Registries also can provide an opportunity for emitters to gain credit for early voluntary reduction prior to the establishment of any mandatory program.

Wisconsin, California, Georgia, and Oregon have, or are developing, some form of a voluntary greenhouse gas registry. Wisconsin, California, and New Jersey have very broad programs that include emissions reductions from several sources, plus some forms of carbon sequestration. Georgia and Oregon are focused more on carbon sequestration through agriculture and forestry. California is the most rigorous in terms of verification and accounting standards.

New Hampshire and New Jersey also have voluntary registries that are now being harmonized with the Regional Greenhouse Gas Registry, which is managed by the Northeast States for Coordinated Air Use Management (NESCAUM).

In August 2005, the Lake Michigan Air Directors Consortium (LADCO) initiated a project to develop a voluntary greenhouse gas registry for the states of Illinois, Indiana, Michigan, Ohio, and Wisconsin. The first phase of this work is to prepare an options paper and the second phase is to develop program guidance by August 2006.

Key issues that must be addressed in registering reductions:

- How to quantify and verify emission reductions?
- Which emissions sources would participate?
- How to account for and verify carbon sequestered in soil, forests, and geologic formations?
- How the voluntary emission reductions may be used (i.e. for current credit trading programs, banking credits against future programs, etc.)?
- Who administers the registry?
- What is the cost to administer the registry?
- How will the administration of the registry be funded?

FOUNDATION FOR ACTION

The Ohio EPA is been participating in an effort to develop a voluntary greenhouse gas registry through LADCO. The registry would be comprised of its five member states—Ohio, Illinois, Indiana, Michigan, and Wisconsin.

The Ohio Air Quality Development Authority and American Electric Power participate in the Chicago Climate Exchange, in which they voluntarily purchase offsets for their greenhouse gas emissions.

Recommended Measures

Voluntary State Registry for Greenhouse Gases

Ohio should continue participating in the creation of a greenhouse gas registry under LADCO, while exploring the option of creating a state-based registry in Ohio. The Ohio EPA, the Ohio Department of Natural Resources, the Ohio Department of Development, and the Ohio Department of Agriculture should form a working group that develops a program for Ohio. By focusing simultaneously on both developing a regional program and developing an Ohio-specific program, the state can ensure that it will play a key role in developing aspects of the regional program while retaining the ability to focus on registry opportunities that are of particular interest or value within Ohio.

Participating in a Voluntary Greenhouse Gas Trading System

The State of Ohio, local governments, and civic organizations should participate in voluntary greenhouse gas programs. Currently, the only voluntary program is the Chicago Climate Exchange (CCX). The State of New Mexico recently joined CCX. American Electric Power and the Ohio Air Quality Development Authority are Ohio-based participants. Under CCX, participants first develop an emissions baseline—the average of annual emissions during years 1998 through 2001. The participants agree to reduce their emissions 4% below the baseline, and maintain that emissions level until 2010.

Developing a State Aggregation Program

The State of Ohio should develop a state greenhouse gas credit aggregation program to assist farmers, small businesses, and others that are potential sellers of greenhouse gas emission reduction credits. The State of Illinois has developed the Illinois Conservation and Climate Initiative that will serve as an aggregator for potential sellers of credits to CCX. The program is specifically for Illinois sellers of credits relating to conservation tillage, tree and grass planting, and methane reduction projects from feedlots and landfills. A credit aggregator removes some of the liability and transaction costs from individual farmers (*see Bio Sequestration and Products and Methane sections for more details*).

Develop a Public Greenhouse Gas Credit Purchase/Reverse Auction Program[81]

Ohio should adopt a public greenhouse gas reduction purchase program that would buy greenhouse gas credits through an auction. The program should be initially developed by directing a portion of the Ohio's Energy Loan Fund to a program that pays for greenhouse gas reductions on a dollar per ton basis. This is analogous to the small renewables grants program developed under the Fund. A useful program could probably be launched for as little as $1 million per year (1/15th of the rider level used to develop the fund at year 2005 funding levels).

An analogous program to the one proposed here is currently used by the State of Georgia in its effort to reduce water consumption during drought. Georgia pays farmers to forego rights to water that these farmers normally would use for irrigation. The funds are given to those farmers who offer to reduce their water consumption for the least cost.

Work With Other States to Develop a Midwestern Regional Greenhouse Gas Trading Program

Ohio should work to develop a region wide greenhouse gas trading program in the Midwest. Several states are involved in regional efforts to directly or indirectly address greenhouse gases. These efforts include: a mandatory greenhouse gas market program in the Northeast; a similar early effort in West Coast states; a clean energy program being developed through the Western Governor's Association; and Power the Plains–a consortium of state legislators, industry, and NGO's from the Great Plains states that are working to develop regional clean energy strategies.

The program most applicable to a greenhouse gas market is the Regional Greenhouse Gas Initiative (RGGI). Several states, including New York, New Jersey, Vermont, New Hampshire, and Maine have agreed to mandatory limits on greenhouse gases from their power sector. The states must maintain 2005 emission levels between 2009 and 2015, and then reduce those emission levels 10% by 2019.

Next Steps for Building Greenhouse Gas Markets

1. The Governor should establish an interagency task force to set up a greenhouse gas registry in Ohio and to ensure robust participation on behalf of Ohio in the creation of the regional registry by LADCO. This task force should include the Ohio Department of Development, the Ohio EPA, the Ohio Department of Agriculture, the Ohio Department of Natural Resources, the Public Utilities Commission of Ohio, and the Ohio Air Quality Development Authority. The Ohio General Assembly should work with state government agencies, commercial interests, and NGO's to adopt any necessary statutory language to develop a program in Ohio.

2. NGO's, state government agencies, and businesses interested in participating in a voluntary program should contact CCX to identify the necessary steps for joining and evaluate the cost for participating in the program.

3. The State of Ohio should work with NGO's, businesses, and other interested parties to develop a state-based aggregator program for Greenhouse Gas credits that could be sold into the Chicago Climate Exchange or other potential markets such as RGGI.

4. The Ohio Department of Development should outline and seek public input on a credit purchase program. The Department, NGO's, and commercial interests should work with the General Assembly to develop statutory changes that maintain the Energy Loan Rider at 2005 levels as a potential funding source.

5. The State of Ohio should engage other states in the region in a discussion aimed at ultimately creating a Midwest regional greenhouse gas trading program. Ohio should explore initiating a dialogue through existing structures, such as the Great Lakes Governors Association. Ohio also should independently reach out to other states to establish a regional dialogue with the sole purpose of promoting clean energy technology and a greenhouse gas market initiative.

Co-Benefits from Building Greenhouse Gas Markets

Greenhouse gas markets provide an opportunity to generate an income stream for technologies and practices that reduce or offset emissions. Landfill operators that capture additional methane or farmers that move from conventional tillage to no-till farming can benefit economically by selling their emissions reductions and offsets as credits.

Additional benefits include:

- Providing an opportunity for parties to potentially receive credit for reductions or offsets taken today against future regulatory regimes.
- Providing a cost efficient method for parties to develop a voluntary emissions reduction program.
- Providing an opportunity to understand the costs and price structure associated with various technology solutions.
- Helping to generate utilization of the "low hanging fruit" opportunities for greenhouse gas emission reductions or offsets.

As noted in the *Methane* and *Bio Sequestration and Products* sections, many of these projects can have additional benefits such as reduction of neighborhood nuisance issues and water quality improvements.

Costs

The cost of participating in a greenhouse gas credit trading system can be evaluated based on the cost per ton of emissions reduced or offset.

For the voluntary Chicago Climate Exchange credit trading program, the costs of reducing or offsetting one metric ton of greenhouse gas emissions generally has traded between $1.00 and $2.00 per ton from 2003 through 2005. However, as of April 2006, the credit price has reached $3.50.[82]

For the Northeastern States' mandatory Regional Greenhouse Gas Initiative, mechanisms in the program are designed to help ensure the credit price is no higher than $10 per ton of CO_2. In terms of economy-wide impacts, the RGGI states estimate that the program will result in an increase of up to 4% for gas prices and $22 per year for the average household's electric usage by the year 2021.[83]

The European Union recently adopted a trading program to assist member countries in meeting the emission limits under the Kyoto Protocol. As of April, 2006, CO_2 credits in this market are trading at $35 per metric ton.[84]

MEASURING SUCCESS

Carbon Budget Impacts

Near-term Carbon Budget Savings[85]

Markets, in general, are the most efficient way to allocate resources. Similarly, greenhouse gas markets are one of the most efficient methods of reducing emissions. It would therefore be an important tool for near-term, cost-effective emission reductions.

Long-term Carbon Budget Management[86]

Presumably, greenhouse gas markets will continue to play a major role in the long-term. However, it is impossible to predict how they will specifically play a role in meeting carbon budgets. There is some discussion that while they are efficient tools for reducing emissions with existing technology, they need complementary efforts to promote technology innovation and development.[87]

Specific Greenhouse Gas Reduction Examples[88]

A greenhouse gas market would most likely result in investing in the "low cost/low hanging fruit"–such as waste methane to power projects and soil sequestration projects (which are relatively low cost projects, and thus can provide a low price on credits). The total annual estimated reduction potential from those two opportunities is 51,222,402 tons of CO_2 (12.7 MMTCE).

While it is sometimes more complex to apply to a credit trading system, energy efficiency is an investment which pays for itself over time and therefore could also be a "low hanging fruit" as well. The total annual reduction potential from the demand reduction programs recommended in the *Electric and Heating Efficiency* section provides a small estimated reduction initially of 8,469,846 tons of CO_2 (2.1 MMTC) in 2010 from business as usual emissions growth, but ramps up over time to an estimated 25,127,209 tons of CO_2 by 2020 (6.23 MMTC) and continues to grow each year.

HYDROGEN/NEW ENERGY SYSTEMS

Part One of the *Ohio Climate Road Map* explained why carbon dioxide emissions will have to be reduced between 65% and 95% by the end of this century, and continue to decline in the next century, if we are to maintain atmospheric greenhouse gas concentrations at a level that will limit global warming. For electricity generation, advanced fossil generation in combination with renewable energy and energy efficiency can deliver such a result. However, meeting such a deep reduction in emissions may not be physically possible through improved vehicle and process heating energy efficiency. Thus, no or low carbon fuels for these sectors will need to be widely available by mid-century and available in sufficient amounts to begin this transition well before then. By definition, widespread use of no or low carbon fuels by mid century would meet or exceed CO_2 emission reduction targets for Ohio.

Technology Options

There are two emerging pathways to a low or no carbon energy system–hydrogen-based power and electrification. It is unclear which of these pathways will emerge as dominant or whether the future energy system will be a hybrid of both paths.

Low or No Carbon Fuels

Sources

Almost all the sources that produce low or no carbon fuels produce electricity as well. Therefore it is likely that the fuels will primarily be utilized in the vehicle and heating sectors. The sources that can provide low or no carbon fuels include:

- Electrolysis–using electricity to split water into hydrogen and oxygen. Sources of low or no carbon hydrogen for this technology include:
  - Renewable energy systems (solar, wind and some biomass)
  - Nuclear power
  - Fossil energy systems with carbon capture and geologic sequestration–breaking down hydrocarbons (fossil fuel) into hydrogen and carbon, then capturing and sequestering the carbon. Coal gasification with carbon sequestration is an example of this technology.
- Biofuel production–Fermentation, pyrolysis, and gasification are all processes that potentially can turn bio material into a low or no carbon fuel.

Fuel/delivery systems

The options for fuel types and their delivery systems are the most challenging from a technical and economic perspective. The primary options for vehicles and heating systems include:

- Hydrogen–Hydrogen fuel for residential, commercial, and industrial purposes has some system advantages. Like natural gas, hydrogen can be delivered through a pipeline to customers. While the natural gas pipeline system is unsuited for a pure hydrogen delivery system, it is suitable for delivering a mixture of hydrogen and methane (hythane) that can be combusted in boilers, furnaces, and stoves. This opens the possibility for a more gradual evolutionary change for the heating and industrial facilities sector. The use of hydrogen in vehicles faces greater technical obstacles. Absent breakthroughs in hydrogen storage technologies (such as binding hydrogen to a solid material), the low energy density of hydrogen has serious limitations for vehicles requiring large travel distances like long haul trucks, suggesting most likely applications will be in areas of high population density.[89]

- Hydrogen-rich synthetic liquid (HRSL) fuels–Examples of HRSLs include ethanol, dimethyl ether (DME), and methanol. These fuels[90] are likely to be produced using hydrogen from gasification (e.g. coal, biomass, etc.) with partial carbon capture and storage. DME (non-toxic, non-carcinogenic) may be an important bridge fuel to a no or low carbon HRSL fuel because it potentially can compete with petroleum on a cost basis but emits a third less CO_2 on a tailpipe basis. Ultimately, for HRSLs to be no or low carbon, they will have to be produced from hydrogen and atmospheric carbon. Currently, the syn-gas from a gasification facility is composed of hydrogen and carbon monoxide (CO)–the basic feed stock to form hydrocarbons. If the carbon from a fuel source (such as coal) is geologically sequestered, then another source of carbon (atmospheric carbon) would be used to create the HRSL. This would, in effect, produce a no or low carbon fuel that could be used in an internal combustion engine. While CO_2 is used as a chemical feed stock in some industrial applications, it is unclear how much more expensive fuel production would be over tradition synthetic gas, which utilizes CO.
- Bio fuels–As a long-term energy system fuel, bio feed stock has an inherent limitation in that most productive land will be focused on food production. Further complications may include competition for such limited feed stocks for potentially highly-economic, non-mobility applications (for example bio-char fertilizers with long-term soil carbon sequestration) that may place additional limit on the availability of "greenhouse gas-neutral" bio fuels.

Power Technologies

The power technologies for vehicles and heating include:

- Hydrogen fuel cells–Fuel cells generate electricity in the form of direct current (DC) from chemical reactions that take place in the fuel cell. Most fuel cells are powered by hydrogen. For many potential applications, commercial fuel cells are years or decades away. However, there are some current and near-term commercial applications. One potential near-term application includes vehicles that operate in close proximity to re-fueling locations. The Olympia Ice Bear™, a fuel cell based ice-rink resurfacing vehicle, is currently available on the market, and John Deere is developing fuel-cell agricultural equipment that they believe will be offered within five years.
- Hydrogen or HRSL ready combustion engines–Internal combustion engines can burn on hydrogen. BMW, for example, has developed "dual-fuel" car that can operate on conventional petroleum or hydrogen. Internal combustion engines can operate on HRSLs as well. Flex-fuel vehicles, known as E85 vehicles, are commercially available and can run on an 85% ethanol fuel.

Electrification

Sources

The carbonless sources of electricity are the same as the carbonless sources for hydrogen.

Delivery Systems

The delivery system for electricity is simply the electric transmission and distribution system.

Power Technologies

Heating–Electric heating systems for commercial and residential needs are already commercially available. However, electricity is unlikely to be able to serve the needs for industrial steam.

Vehicles–Battery based vehicles are the primary power technology for no carbon electrification.

Key Issues

Because most no or low carbon fuel production options are also electricity generation options, the future fuel production system is more likely to be decentralized than today's refinery system–with the same facilities producing electricity and fuel. This is challenging as power and mobility systems are today entirely separate and disconnected. Most conventional analyses of these systems assume that this will persist over time. Therefore, identifying a straightforward development path is difficult.

The most economic path to no or low carbon vehicle systems may be through the use of HRSLs and advanced conventional vehicles such as "plug-in" electric hybrids. In both cases, there are carbon issues that must be addressed during system transitions. HRSL development is likely to occur through the advancement of "conventional" synthetic fossil fuels production (e.g. synthetic diesel fuel from coal). However, these "interim" systems would typically produce synthetic gasoline and diesel fuel with about 1.8 times the greenhouse gas emissions of conventional fossil fuels, unless the system includes carbon capture and sequestration. Likewise, the greenhouse gas emissions profile of advanced conventional vehicles, such as "plug-in" hybrid electric vehicles, have a higher greenhouse gas emission profile than petroleum for the portion of the power than comes from conventional coal-fired power electricity grid.

One of the most useful paths for developing a hydrogen-based distribution system may be the strategic introduction of hythane (hydrogen-methane mixture) into the natural gas system.

While the hydrogen/fuel cell combination may be one of the most challenging technical paths for no or low carbon energy sources, it has important long-term advantages:

- Fuel cells have the potential to be more efficient than internal combustion engines.
- While fossil based no or low carbon systems may be a key technology for this century, the supply of inexpensive fossil fuels are inherently limited, whereas hydrogen can be produced from renewable energy sources.

FOUNDATION FOR ACTION

Ohio's Third Frontier Fuel Cell Program is a $100 million grant program designed to support the commercialization of fuel cells, focusing on research and development that addresses technical and cost barriers and adapting fuel cell components produced in Ohio for use in fuel cell systems.

Recommended Measures

Near-Term Technology Utilization and Market Development

Fueling Infrastructure Fund

Ohio should establish a revolving loan program to provide capital for the construction and installation of vehicle refueling infrastructure for bio fuels and hydrogen and bio fuels or hydrogen blended with other fuels, fuel cells or related technologies.

Tax Incentives for Near Term Fuel Cell Commercial Products

Ohio should develop an investment tax credit or accelerated depreciation schedule for larger fuel cell applications and a sales tax credit for consumer products (such as cell phones or laptops) that use fuel cell technology. For the larger fuel cells, this will most likely only be relevant in the near-term for products such as ice finishing machines and farm equipment.

State Procurement Guidelines

Ohio should follow recent federal requirements included in the Energy Policy Act of 2005 and develop a hydrogen technology section in its purchasing guidelines and contracts. This will help streamline and accelerate procurement of hydrogen, fuel cells and related technologies.

Key Opportunities for Research, Development and Demonstration Projects

Bio Char Production for Fertilizer and Hydrogen-Based Farm Equipment

Ohio should look for intersectional opportunities to develop near-term projects that will help commercialize new energy technologies while also serving the state's economic base. For example, bio char pyrolysis research (including hydrogen production) can be combined with early commercialization of fuel cell farm equipment to develop an integrated fertilizer and fuel production system (*for details on bio char see the Bio Sequestration and Products section*).

Plug-in Hybrid Community Demonstration Program

Vehicle manufacturers and utilities work with a local community to "road test" how plug-in hybrids could be integrated into local transportation needs. A variety of local private and public fleets could be utilized to explore the more immediate practical niches for using this technology.

Synthetic Gas to Hythane and HRSLs

The development of near-term coal gasification projects, such as coal to diesel or coal to methane, could provide the platforms for the production of future no or low carbon fuels (assuming geologic sequestration of carbon). As these projects are developed, low carbon fuels research and development opportunities should be considered. For example, a coal to methane facility that is connected to a natural gas transmission or distribution pipeline provides an excellent opportunity to study how hythane may be integrated into the current natural gas system. Likewise, a facility that produces diesel from coal through the Fischer Tropsch process can be a platform to study how high density hydrogen (low carbon) fuels can be deployed through the existing fuel distribution infrastructure.

Multi-Sector New Energy Models

Ohio's academic institutions and state programs such as the Ohio Third Frontier program should take the lead in developing a model for a new energy infrastructure in Ohio which integrates the electricity, transportation, and thermal sectors. Emphasis should be placed on how the interaction between the sectors affects cost and total value to the economy.

Next Steps for Promoting Hydrogen/New Energy Systems

1. State agencies, trade associations and NGOs should develop a working group to consider how to initiate a small scale infrastructure revolving loan fund.
2. Lawmakers, NGOs, and the Ohio Fuel Cell coalition should work to develop tax incentives for near-term commercial fuel cell products
3. The Department of Administrative Services should confer with relevant federal agencies regarding the implementation of fuel cell procurement requirements in the Energy Policy Act of 2005.

4. The Governor should develop a working group to identify key research, development and deployment projects for the next generation energy markets, such as those mentioned above. The projects could potentially be leveraged through state activities, such as the Third Frontier Project and Ohio FutureGen Task Force.
5. The Third Frontier Project should issue a request for proposal to state universities for a collaborative effort to develop an energy transition infrastructure model.

Co-Benefits from Promoting Development of Hydrogen/New Energy Systems

Virtually all the potential no or low carbon energy systems promote energy security by including the benefit of having a primarily domestic fuel source.

As with any technology shift, transitioning to a no or low carbon energy future will create tremendous opportunities for innovation and economic development.

Costs

Any major change in energy infrastructure will cost hundreds of billions of dollars. However, most of these costly infrastructure changes (electric and gas transmission and distribution, gasoline refueling networks) have added substantial value to our economy. For example, based on the cost figures described in the Advanced Coal and Carbon Sequestration section of this report, the eventual replacement of Ohio's base-load coal plants could cost $20 to $30 billion in capital costs alone.

It is likely the modest tax incentive and research programs described in this section will cost several million dollars. However, determining the most cost-effective economically value-added path will be well worth the investment.

MEASURING SUCCESS

Carbon Budget Impacts

Near-Term Carbon Budget Savings[91]

As developing new energy systems will be a long-term process, there are unlikely to be any near-term greenhouse gas emission reduction benefits.

Long-Term Carbon Budget Management[92]

A successful energy transition strategy will, by definition, meet or exceed the carbon budget cuts that are needed for climate stabilization.

Specific Greenhouse Gas Reduction Examples[93]

One specific energy transition technology strategy, not covered in the other sections of this report, is gradually infusing natural gas with hydrogen to reduce the carbon dioxide emissions that results from natural gas combustion. The mix of hydrogen and natural gas is call hythane. A strategy of replacing 50% of natural gas with hydrogen, in combination with coal gasification and carbon sequestration for industrial heat would reduce annual emissions from the thermal sector by an estimated 71,462,335 tons of CO_2 (17.72 MMTC) by the end of the century.

CLEAN DIESEL

Nearly a third of Ohio's 88 counties are challenged with meeting the new federal air quality standards for ground-level ozone (33 counties) and fine particles (24 full counties and three partial counties). In addition to serious health impacts, ground level ozone and certain types of fine particles (black carbon) also have significant climate impacts. In its efforts to meet federal air quality standards, Ohio should focus on strategies that maximize the climate cooling benefits that come from reducing these particular pollutants. Utilizing cleaner fuels and emission reduction technologies can reduce diesel black carbon by 90% in Ohio over the next 20 years and maintain low levels of emissions going forward.

Technology Options

Black carbon is the elemental carbon portion of the fine particulate matter in diesel exhaust. There are many effective technology options for reducing harmful diesel emissions, but only a subset of those are particularly effective in reducing black carbon emissions–this subset is listed below.

Diesel Particulate Filters

Diesel particulate matter is largely comprised of elemental (black) carbon particles, organic particles, and sulfates. Diesel particulate filters (DPFs) remove up to 95% of the particulate matter, including black carbon, from the diesel exhaust. New federal rules require on-road heavy diesel engines (trucks and buses) to include DPFs starting with the 2007 model year. Non-road heavy diesel engines (construction and agricultural equipment) will be required to have the DPFs included starting in 2008 through 2014, based on engine horsepower. Many on- and non-road vehicles can be retrofitted with DPFs as well.

The U.S. EPA is considering the adoption of an emissions reduction rule for locomotive engines and domestic marine vessels that would require the use of DPFs for those engine types. While marine vessels may be retrofitted with DPFs, locomotive engines are more challenging. The California Air Resources Board is testing the replacement of locomotive engines with a series of smaller heavy engines that are equipped with DPFs.

Only electronically controlled engines, usually model year 1994 or later, are capable of using DPFs.

Ultra Low Sulfur Diesel

Ultra Low Sulfur Diesel (ULSD) contains less than 15 parts per million of sulfur. While it does not significantly reduce black carbon emissions (it reduces particulate matter emissions only 10%), the low sulfur content is necessary in order for DPFs to function properly. Thus the federal rule requiring DPFs on new diesel engines starting in 2007 also requires all on-road vehicles to use ULSD as of October 2006 and all non-road vehicles to use ULSD by 2010.

Emulsified Diesel

Diesel-water emulsion is a water and diesel fuel blend additive manufactured by Citgo and Lubrizol that reduces emissions by cooling the combustion temperature. Lubrizol claims an overall particulate matter reduction of 54%, but believes the process reduces most of the black carbon emissions. These additives can also reduce ozone-forming nitrogen oxide emissions by 5% to 20%.

Idling Reduction

Idling trucks and locomotives consume over one billion gallons of diesel fuel in this country annually, with trucks using 960 million gallons and locomotives 60 million gallons. This results in 5,000 tons of particulate matter emitted into the atmosphere each year from long-duration truck idling alone. The U.S. EPA has estimated that a typical truck burns 0.8 gallons of fuel for each hour that it idles. Researchers with the U.S. Department of Energy found that overnight idling accounts for almost 25% of all truck running time. Therefore, idling reduction can significantly reduce fuel costs as well as engine wear.

Solutions to reduce unnecessary idling include operational policies; on-board hardware in the form of engine pre-heaters, direct-fired heaters, and auxiliary power units; and truck stop electrification.

Re-powering

Replacing an older engine in a diesel-powered vehicle with a newer engine that includes pollution controls is one approach that can be used to allow an existing vehicle to use DPFs. For this reason, re-powering is often used to replace a pre-1994 engine with a newer electronically-controlled engine that can handle advanced retrofits like a DPF.

FOUNDATION FOR ACTION

Ohio Senator George Voinovich led the passage of the Diesel Emissions Reduction Act of 2005 (DERA). Once fully appropriated, DERA will provide $1 billion in funding over five years to assist public vehicle fleets with adopting diesel emissions retrofit controls. The OEC—along with diesel manufacturers—strongly supported the legislation and worked for its adoption.

Substitute Ohio House Bill 245 (Reinhard) (*see Bio Sequestration and Products section*) would create an Ohio-based diesel clean-up grants program that would be eligible to receive federal DERA funding.

The Mid-Ohio Regional Planning Commission (MORPC) developed a multi-county diesel emissions reduction plan to reduce local diesel emissions to help meet federal air quality standards. This groundbreaking initiative was a collaborative effort of industry, government, public health and nongovernmental organizations.

The State of Ohio has developed, through Ohio EPA, a $1 million grants program that will help school districts retrofit diesel-powered school buses with pollution control equipment and use cleaner fuels to reduce emissions.

All major Ohio metropolitan areas, and some smaller communities in Ohio, face non-attainment with federal air quality standards for fine particulate matter and/or ground level ozone. Federal law requires most communities to meet federal ozone standards by 2009 (2010 for the Cleveland-Akron-Lorain area, which has been designated a “moderate” non-attainment area) and federal fine particle standards by 2010.

Cleveland-based Lubrizol Corporation manufactures emulsified diesel fuel–a potential black carbon control strategy. Lubrizol’s PuriNOx product can also reduce ozone-forming nitrogen oxide emissions by 5% to 20%.

A growing number of voluntary efforts currently are underway in Ohio. At least a dozen school districts (including Bexley, Cleveland, Cincinnati, Westerville and a few county boards of MR/DD) have secured highly competitive federal grants to install pollution controls and switch to cleaner fuels. Several truck carrier operations based in Ohio are SmartWay Transport Partners–a voluntary collaboration between U.S. EPA and the freight industry designed to increase energy efficiency while significantly reducing greenhouse gas emissions and air pollution.

Replacement

In some cases it may not be cost-effective in the long run to re-power or rebuild an older diesel engine. Instead, fleets may retire the oldest, heaviest emitting vehicles and purchase a new vehicle with the latest emission controls.

Recommended Measures

Voluntary Diesel Vehicle Fleet Clean-Up Efforts

As noted in *Foundation for Action*, there are several examples of both public and private companies that have initiated a voluntary diesel clean-up effort. Business and government agencies in Ohio should take the opportunity to develop an emissions clean-up program for their heavy vehicle fleets. When applicable, fleets should take advantage of state and federal grant and loan opportunities to help fund clean diesel projects.

Requiring Best Available Control Technology for All On- and Off-Road Vehicles

Ohio EPA should develop new rules requiring diesel-powered vehicle fleets to install Best Available Control Technology (BACT) on all vehicles, phased in over a period of years, as part of its effort to help Ohio meet federal air quality standards. In this case, BACT means the technology that is appropriate for the specific vehicle or equipment being modified and which provides the maximum reduction of targeted emissions considering both tons of emissions avoided and diesel emissions exposure within affected populations. Choosing the appropriate pollution control technology depends on a variety of factors, including: age of the engine, duty cycle, expected life and vehicle miles traveled each year.

When developing a BACT program for these fleets, Ohio EPA should consider including the opportunity for compliance extensions for carefully defined hardship circumstances; for example, smaller waste collection businesses and local governments should have the opportunity to demonstrate that they require additional time to comply with a BACT program because of financial hardship.

Emission Performance Guarantees in Government Contracts

The State of Ohio should work with representatives of the construction industry, government contracting agencies, and environmental advocacy and other interested citizens groups to establish a program of improved emissions performance specifications in contracts of substantial public works projects (such as projects over $2 million in total cost), including all major highway, bridge and public building construction projects.

An effort should be made to accelerate the introduction of ultra-low sulfur diesel (ULSD) fuel or other fuel with equal or greater emissions performance by mandating its use in public construction projects where equipment is fueled on-site through either visiting fuel jobbers or on-site tanks. The early use of ULSD (prior to the 2010 deadline) in the off-road sector could play an important role in reducing diesel particulate matter and facilitate meeting federal air quality standards.

Diesel Retrofit Incentive Programs

There has been some progress toward providing funding to assist with voluntary retrofit programs. The new federal DERA program, once fully appropriated, will provide a significant source of funding for projects in Ohio. U.S. EPA currently administers highly competitive grant programs such as Clean School Bus USA and the Voluntary Diesel Retrofit Program. These programs will be bundled under DERA when funds are appropriated. The Ohio EPA's Diesel School Bus Retrofit Grant program is anticipated to generate about $1 million in retrofit assistance from enforcement dollars between 2006 and 2007. The Ohio General Assembly should authorize the continuation and funding of this program beyond 2007.

However, the dollars from these programs are still relatively small compared to what is needed to retrofit the millions of existing diesel engines in the U.S. The State of Ohio should establish a grant fund or loan program to assist both public and private fleets with the purchase and installation of emission control equipment. In addition, the state should develop a program of low interest, state bond-supported bridge financing to assist state and local governments in increasing the replacement of older, higher emitting equipment.

Idling Reduction Programs

Public Fleets

Ohio should establish a mandatory statewide school bus idling regulation.

Ohio should create an incentive to reduce idling by establishing a revolving loan or lease-to-own program to assist fleets with the initial purchase of idling reduction equipment.

The Ohio Department of Administrative Services should require all new fleet purchases under its purview to include anti-idling devices.

Private Fleets

Ohio should promote a voluntary idling program with educational outreach for a limited time; the next phase would be to establish a mandatory statewide policy.

The State of Ohio should set contract requirements for public projects using private fleets to require the use of idling reduction operational policies and/or hardware to reduce emissions in the communities served.

Ohio should create a revolving loan or lease-to-own program for purchasing anti-idling equipment for private fleets and private owners.

Ohio should develop a program to reduce idling from switchyard locomotives.

Truck Stop Electrification

Ohio should work with the trucking industry and neighboring states to identify key sites for truck stop electrification (TSE) along heavily traveled corridors on major trucking routes.

The Ohio Department of Development's Office of Energy Efficiency, Ohio EPA and the Ohio Air Quality Development Authority should work together to establish a financing program for qualifying sites for truck stop electrification projects, and assess the benefits and feasibility of developing a large network of TSE facilities in Ohio.

The Ohio Department of Transportation (ODOT) should require that all newly constructed public rest stops/ truck stops include the electrical infrastructure necessary to meet the increasing demand of long haul transportation on Ohio's roadways and air quality requirements.

Diesel Fleet Inventories

Ohio EPA should conduct a study to obtain fleet inventories of all diesel-powered public works vehicles and transit buses and all public and private waste collection vehicles in Ohio's non-attainment counties. Such inventories should include, among other things, the number, age, and type of engines, estimated operational use and annual emissions.

Ohio EPA should conduct a study to obtain fleet inventories for school buses, short-haul freight trucks, cement mixers, and dump trucks in Ohio's non-attainment counties. These inventories are needed to better assess the impact of diesel pollution on the failure of over one-third of Ohio's counties to meet federal clean air standards. A robust inventory would facilitate modeling and emissions estimates by Ohio EPA for utilizing diesel retrofit projects as part of a measurable emissions reduction strategy to be included in the state implementation plan to meet the air standards.

Reducing Train and Ship Emissions

In June of 2004, U.S. EPA announced it is considering issuing proposed rules in the 2005-2006 time frame that would require substantial reductions in emissions of particulate matter, nitrogen oxides, and hydrocarbons from locomotive and most commercial marine diesel engines beginning in about 2011. Interested parties from Ohio should urge the U.S. EPA to move forward with this rule making.

Meanwhile, the Ohio EPA should consider options associated with non-attainment that would help drive the adoption of DPFs on locomotives and domestic ships. Options could include promotion of voluntary measures, emission requirements on vessels that use ports in Ohio, and Best Available Control Technology for locomotives as part of engine re-powering.

Co-Benefits from Clean Air

Emissions from diesel engines contribute to an estimated 769 premature deaths each year in Ohio. The cancer risk from diesel soot pollution is nine times greater than the combined cancer risk of all other air toxics combined. Diesel engines are Ohio's number one source of air toxics emissions.[94]

Clean air not only provides a better quality of life for Ohioans, it also avoids the economic development challenges that come from failing federal air quality standards: restrictions on new and expanding businesses, tightened transportation planning options and the potential loss of federal highway dollars.

Costs

The cost of pollution controls for in-use diesel engines varies greatly.

Diesel particulate filters (DPFs) cost between $4,000 and $10,000 per vehicle for on-road vehicles and between $10,000 and $30,000 for non-road vehicles.[95]

According to manufacturer estimates, emulsified diesel fuel may add between $0.30 and $0.50 to the cost of diesel fuel per gallon.[96]

Engine re-powering—in which an older engine in a diesel-powered vehicle is replaced with a newer engine and an after treatment device--can cost between $5,000 and $75,000 for on-highway diesel vehicles, such as trucks and school and transit buses. Re-powering for off-road diesel engines, such as construction and farm equipment, can range from $15,000-$100,000.

MEASURING SUCCESS

ìQuick and Cheap Coolingî from Other Emission Reductions[97]

The “residence time” of pollutants such as black carbon or ozone in the atmosphere is measured in days or, at most, weeks. Therefore, the cooling benefits from their reduction can be felt virtually immediately by our climate. In addition, reducing these pollutants can be achieved cost effectively by making strategic choices with regard to how to meet the federal air quality standards by, for example, retrofitting diesel engines with particulate filters (up to a 90% cut in fine particle emissions, including black carbon emissions) rather than a diesel oxidation catalyst (up to a 30% cut in fine particle emissions, but not the black carbon portion) when possible.

Specific Greenhouse Gas Reduction Examples[98]

Black carbon emissions from diesel engines can potentially be reduced by 90% over the next 20 years. For Ohio, this level of reduction would be the equivalent of reducing an estimated annual 9,800,082 tons of CO_2 (2.43 MMTCE) from year 2000 levels.

REFERENCES AND CASE STUDIES

Bio Sequestration and Products

Midwest Regional Carbon Sequestration Partnership
http://198.87.0.58

Ohio Energy Action Plan
www.governor.ohio.gov/releases/022406energyday.htm

Ohio State University Carbon Management and Sequestration Center
www.cmasc.osu.edu

Ohio Bioproducts Innovation Center
www.bioproducts.osu.edu

Wisconsin Biorefining Development Initiative
www.wisbiorefine.org

Maine Forest Service
www.maine.gov/spo/natural/gov/docs/NRBICarbonPres032505.ppt

Environment Northeast
www.env-ne.org/Climate_Change_Global_Warming_Solutionsold.htm

The Minnesota Project–Farming and Soil Carbon
www.mnproject.org/pdf/Farming-Carbon%20final_web_10-20-05%20(3).pdf

U.S Department of Agriculture Crop Insurance Program
www.rma.usda.gov/aboutrma/what/history.html

Biochar
www.eprida.com

Advanced Coal Generation and Carbon Sequestration

Midwest Regional Carbon Sequestration Partnership
http://198.87.0.58

National Energy Technology Lab (U.S. Department of Energy) gasification program
www.netl.doe.gov/technologies/coalpower/gasification/index.html

National Energy Technology Lab (U.S. Department of Energy) carbon sequestration program
www.netl.doe.gov/technologies/carbon_seq/index.html

State of Illinois coal gasification incentive program
www.illinoisbiz.biz/dceo/Bureaus/Coal/Programs/Illinois+Coal+Revival+Program.htm
www.illinoisbiz.biz/NR/rdonlyres/5AB6BA42-79DA-430D-8774-CC3EF2DCFDC8/0/0940065.pdf

Pennsylvania Advanced Energy Portfolio Standard
www.depweb.state.pa.us/energy/lib/energy/docs/section2technicalguidancefinal.pdf

Electric Heating and Efficiency

The Appliance Standards Awareness Project
www.standardsasap.org

The Energy Center of Wisconsin
www.ecw.org

Energy Efficiency Resource Standards: Experience and Recommendations
www.aceee.org/press/e063pr.htm

Midwest Combined Heat and Power Application Center
www.chpcentermw.org/home.html

U.S. Combined Heat and Power Association
www.uschpa.admgt.com

U.S. EPA's Combined Heat and Power Partnership
www.epa.gov/chp

U.S. Green Building Council
www.usgbc.org

Methane

Landfill methane
www.epa.gov/lmop/index.htm

Rachel Goldstein
Phone: (202) 343-9391; Email: goldstein.rachel@epa.gov

Agricultural methane
www.epa.gov/agstar/index.html

Kurt Roos
Phone: (202) 343-9041; Email: roos.kurt@epa.gov

Agricultural Biogas Casebook–2004 update (prepared for Great Lakes Regional Biomass Energy Program)
www.rs-inc.com/AgriculturalBiogasCasebook2004Update.pdf

Ohio Biomass Energy Program
www.puco.ohio.gov/Puco/IndustryTopics/Topic.cfm?doc_id=332

Turning Manure into Gold
www.puco.ohio.gov/emplibrary/files/util/biomass/publications/TurningManuretoGold.pdf

Coal Mine methane
www.epa.gov/cmop/index.htm

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Natural Gas Infrastructure
www.epa.gov/gasstar

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Carey Bylin
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Cattle Feed Modification
www.epa.gov/agstar/index.html

The EPA AgSTAR Hotline
Toll-free (800)-95-AgSTAR or (800) 952-4782

Vehicle Efficiency

Electric Drive Transportation Association
www.electricdrive.org

Plug-in partners
www.pluginpartners.org

Eaton/Fed Ex/Environmental Defense partnership
www1.eaton.com/hybrid_vehicle

Hydraulic Hybrid products
www.parker.com/Products/Interactive/RunWise/
www.peterbilt.com/index_new_mor.asp?file=1658&archivedate=

Homogeneous Charge Compression Ignition (HCCI)
www.me.berkeley.edu/cal/HCCI

Wind and Solar

Wind Turbine Development: Location of Manufacturing Activity, Renewable Energy Policy Project
www.crest.org/articles/static/1/binaries/WindLocator.pdf

Basic Research Needs for Solar Energy Utilization
www.er.doe.gov/bes/reports/files/SEU_rpt.pdf

Database of State Incentives for Renewable Energy
www.dsireusa.org

Building Greenhouse Gas Markets

GHG Registry

The Wisconsin Voluntary Emission Reduction Registry
www.dnr.state.wi.us/org/aw/air/registry/index.html

The California Climate Action Registry
www.climateregistry.org

Georgia Carbon Registry (bio sequestration only)
www.legis.state.ga.us/legis/2003_04/sum/sb356.htm

Oregon Carbon Registry (forest sequestration only)
www.oregon.gov/ODF/PRIVATE_FORESTS/carbon.shtml

The Lake Michigan Air Directors Consortium (LADCO)–for Illinois, Indiana, Michigan, Ohio, and Wisconsin
www.ladco.org/regional_greenhouse.htm

Northeast Regional Greenhouse Gas Registry--Registry project of the Northeast States for Coordinated Air Use Management (NESCAUM)
www.rggr.us

The Greenhouse Gas Protocol Initiative
www.ghgprotocol.org

Voluntary GHG Trading

Chicago Climate Exchange
www.chicagoclimateexchange.com.

Illinois Conservation and Climate Initiative
www.illinois.gov/PressReleases/ShowPressRelease.cfm?SubjectID=18&RecNum=4609

Regional U.S. GHG efforts

Regional Greenhouse Gas Initiative
www.rggi.org

Western Governor's Association Clean and Diversified Energy Initiative
www.westgov.org/wga/initiatives/cdeac/index.htm

West Coast Governor's Climate Initiative
www.climatechange.ca.gov/westcoast/index.html

Powering the Plains
www.gpisd.net/programs.htm

National/Multinational GHG trading efforts

EU GHG Emissions Trading Scheme
www.europa.eu.int/scadplus/leg/en/lvb/l28012.htm

Canadian Plan for GHG emissions trading program
www.climatechange.gc.ca/english/ccplan.asp

Hydrogen/New Energy Systems

The Future of the Hydrogen Economy: Bright or Bleak, Bossel, Eliasson, and Taylor, European Fuel Cell Forum
www.efcf.com/reports/E08.pdf

Before a Transition to Hydrogen Transportation, study currently underway by MIT's Laboratory for Energy and the Environment
www.lfee.mit.edu/metadot/index.pl?id=3753&isa=Category&op=show

EPRIDA, private company focused on the commercialization of bio char
www.eprida.com

Electric Drive Transportation Association
www.electricdrive.org

Upper Midwest Hydrogen Initiative
www.gpisd.net/resource.html?Id=5

Ohio Fuel Cell Coalition
www.fuelcellsohio.org/pages/831560/index.htm

Ohio Third Frontier Project
www.thirdfrontier.com

Clean Diesel

U.S. EPA National Clean Diesel Campaign
www.epa.gov/diesel

Mid Ohio Regional Planning Commission diesel emissions reduction initiative
www.airquality.morpc.org

Texas Emissions Reduction Program
www.tceq.state.tx.us/implementation/air/terp/index.html

California Carl Moyer Program
www.arb.ca.gov/msprog/moyer/moyer.htm

Diesel Technology Forum
www.dieselforum.org

Ohio EPA School Bus Program
www.epa.state.oh.us/oeef

ENDNOTES

1. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp 25-28.

2. Ibid, pp 14-15.

3. Carbon Sequestration Potential in Cropland and Grassland in Ohio, Tan an Lal, in publication. A recent general discussion of agricultural sequestion and climate change by Dr. Lal can be found at "Managing Soil Carbon", Ratan Lal, Michael Griffin, Jay Apt, Lester Lave, and M. Granger Morgan, Science 16 April 2004; 304: 393.

4. Carbon in United States Forests and Wood Products, 1987-1997: State-by-State Estimates by Richard A. Birdsey & George M. Lewis, US Forest Service.

5. Farrell, et.al. Ethanol Can Contribute to Energy and Environmental Goals, Science, Vol. 311, January 27, 2006.

6. William Lazarus, Farm Machinery Economic Cost Estimates for Last 2005, University of Minnesota Extension Service.

7. D. Tiffany, V. Eidman, U. S. Dry-Grind Ethanol Production:Economic Competitiveness In The Face Of Emerging Technologies, University of Minnesota Department of Applied Economics, presented at the 9th Joint Conference on Food, Agriculture, and the Environment, May 2005; J. DiPardo, Outlook for Biomass Ethanol Production and Demand, U.S. Department of Energy, 2002.

8. University of Illinois, Farmdoc,http://www.farmdoc.uiuc.edu/manage/pricehistory/price_history.html

9. D. Tiffany, V. Eidman, U. S. Dry-Grind Ethanol Production:Economic Competitiveness In The Face Of Emerging Technologies, University of Minnesota Department of Applied Economics, presented at the 9th Joint Conference on Food, Agriculture, and the Environment, May 2005.

10. Biomass Cofiring: A Renewable Alternative for Utilities, U.S. Department of Energy Fact Sheet, June 2000.

11. Biomass Feedstock Availability in the United States: 1999 State Level Analysis, Wlash et. al., Oak Ridge National Laboratory, 1999.

12. See explanation of this term in section on Measuring Success.

13. See explanation of this term in section on Measuring Success.

14. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.

15. CO2 Capture and Storage in Geologic Formations, National Energy Technology Laboratory, 2002.

16. Ibid.

17. Ibid.

18. Ibid.

19. Annual Project Report to Ohio Coal Development Office from Applied Sciences, Inc. OCD Grant No. CDO/D-99-14.

20. Electric Power Research Institute, 2004.

21. Carbon Sequestration Technology Roadmap, National Energy Technology Laboratory, 2004.

22. See explanation of this term in section on Measuring Success.

23. See explanation of this term in section on Measuring Success.

24. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.

25. N. Strachen and A. Farrell, Emissions From Distributed Generation, Carnegie Mellon Electricity Industry Center, CEIC Working Paper 02-04, 2002.

26. Demand-Side Management Actual Peak Load Reductions by Program Category, Energy Information Administration, U.S. Department of Energy.

27. Energy Efficiency and Customer-Sited Renewable Energy: Achievable Potential in Wisconsin 2006-2015, Energy Center of Wisconsin, 2005.

28. Energy Efficiency Resource Standards, American Council for an Energy Efficient Economy, 2006.

29. Appliance & Equipment Efficiency Standards: Opportunities for States in 2006, Appliance Standards Awareness project.

30. Energy Efficiency and Customer-Sited Renewable Energy: Achievable Potential in Wisconsin 2006-2015, Energy Center of Wisconsin, 2005

31. Monthly Electric Utility Sales and Revenue Data, Energy Information Administration, U.S. Department of Energy.

32. Derived from Connecticut Office of Consumers Counsel, Analysis of New England States' Energy efficiency Programs DN-03-11-01. This analysis indicated that for the most robust state programs in New England, demand side management programs produced electricity reductions at a rate 0. 002116 MWH/$ for the residential sector, and reductions at a rate of 0.004296MWH/$ for the commercial and industrial sector.

33. Monthly Electric Utility Sales and Revenue Data, Energy Information Administration, U.S. Department of Energy.

34. See explanation of this term in section on Measuring Success.

35. See explanation of this term in section on Measuring Success.

36. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.

37. Appliance & Equipment Efficiency Standards: Opportunities for States in 2006, Appliance Standards Awareness Project.

38. Ohio EPA, Division of Air Pollution Control, Landfill methane Emissions Inventory

39. Turning a Liability into an Asset: A Landfill Gas to Energy Handbook for Landfill Owners and Operators, USEPA, Landfill methane Outreach Program

40. An evaluation of a mesophilic, modified plug flow anaerobic digester for dairy cattle manure, USEPA, 2005.

41. Climate Change and Greenhouse Gas Mitigation: Challenges and Opportunities for Agriculture. Task Force Report. CAST (Council for Agricultural Science and Technology). 2004.

42. Ibid.

43. Identifying Opportunities for Coal Mine Methane Recovery at U.S. Coal Mines: Profiles of Selected Gassy Underground Coal Mines (1999-2003), USEPA Coal bed Methane Outreach program

44. Data provided by CDX.

45. Australia Profile, Methane to Markets Partnership, Australian Department of Environment and Heritage, pp 8-9; http://www.methanetomarkets.org/resources/coalmines/docs/australia_profile.pdf.

46. Methods for Reducing Methane Emissions from Natural Gas Systems, USEPA Gas STAR program

47. Annual Energy Outlook, 2006, the U.S. Department of Energy, Energy Information Administration.

48. Report on U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions, U.S. EPA, Appendix II, September 1999.

49. Report on U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions, U.S. EPA, Appendix V, September 1999.

50. Report on U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions, U.S. EPA, Appendix IV, September 1999.

51. Report on U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions, U.S. EPA, Appendix III, September 1999.

52. See explanation of this term in section on Measuring Success.

53. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.

54. DeCicco, An and Ross "Technical Options to improve fuel economy of US cars and light-duty trucks" ACEEE publication April 2001; "On the road in 2020" MIT Energy Lab. publication October 2000

55. Ibid.

56. Green Car Congress, October 20, 2004.

57. U.S. EPA Fact Sheet, February 2005 (EPA420-F-05-006).

58. Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options for Compact Sedan and Sport Utility Vehicles. Electric Power Research Institute, 2002.

59. Ibid.

60. Weiss, et.al., Technology and Cost of future fuel economy improvements for light-duty vehicles,Energy and Environment Analysis, Reportto the NAS Committee on CAFE, June 2001.

61. Weiss, et.al., Technology and Cost of future fuel economy improvements for light-duty vehicles,Energy and Environment Analysis, Reportto the NAS Committee on CAFE, June 2001.

62. Future U.S. Highway Energy Use: A Fifty Year Perspective, Technology Cost Resource Paper (draft), U.S. EPA, December 2002.

63. Weiss, et.al., Technology and Cost of future fuel economy improvements for light-duty vehicles,Energy and Environment Analysis, Reportto the NAS Committee on CAFE, June 2001.

64. See explanation of this term in section on Measuring Success.

65. See explanation of this term in section on Measuring Success.

66. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.

67. America Wind Energy Association, Wind Energy Projects, http://www.awea.org/projects/.

68. Repowering the Midwest, Environmental Law and Policy Center of the Midwest, 2002.

69. Wind Energy Resource Maps of Ohio, AWS Truewind, LLC, 2004. http://www.windexplorer.com/Ohio/ohio.htm

70. National Wind Technology Center, U.S. Department of Energy, Low Wind Speed Technology Project, http://www.nrel.gov/wind/wind_project.html.

71. Interview with Eric Ingersoll, President, Mechanology, October, 2005.

72. Co-generation using Wind and Bio-diesel powered generators, Tiffany, Staff paper Series, Department of Applied Economics, University of Minnesota, 2005.

73. Basic Research Needs for Solar Energy Utilization, National Renewable Energy Laboratory, 2006.

74. Ibid.

75. Ibid.

76. Basic Research Needs for Solar Energy Utilization, National Renewable Energy Laboratory, 2006.

77. Ibid.

78. See explanation of this term in section on Measuring Success.

79. See explanation of this term in section on Measuring Success.

80. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.

81. The rationale for government purchase of greenhouse gas reductions as a public good has been well developed by the Carbon Management Initiative program (www.princeton.edu/~cmi/) at Princeton's Center for Energy and Environmental Studies. Key documents describing this approach include, David F. Bradford, "A No Cap But Trade Approach to Greenhouse Gas Control", October 13, 2001, and David F. Bradford and Klaus Keller, "Carbon Dioxide Sequestration: How Much, When, and Who Should Pay?" January 15, 2002. Additional resources include Georgia's Department of Environmental Protection Division of the Department of Natural Resources, (www.gaepd.org)and the Georgia Environmental Facilities Authority (www.gefa.org).

82. From Chicago Climate Exchange Market Data (http://www.chicagoclimatex.com/trading/marketData.html).

83. Retail Rate Impact Analysis, Regional Greenhouse Gas Initiative, 2004 (www.rggi.org).

84. From European Climate Exchange Market Data (www.europeanclimateexchange.com).

85. See explanation of this term in section on Measuring Success.

86. See explanation of this term in section on Measuring Success.

87. A Possible Turning Point for Climate Solutions, How Innovations in Investment, Technology, and Policy are Needed for Emissions Stabilization, Clean Energy Group, 2005.

88. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.

89. Potential limitations of hydrogen gas in mobility applications are explored in some detail in "The Future of the Hydrogen Economy", by Ulf Bossel, Baldur Eliasson and Gordon Taylor, April 2003 and "Toward a Hydrogen Economy" a special section at pages 957–976 of Science, Vol 305, 13 August 2004.

90. Selected HRSLs are as follows:

Ammonia	NH3		
Octane	C8H18	or	CH3(CH2)3CH3
Toluol (Methylcyclohexane)	C7H14	or	C6H5CH3
Ethylbenzol	C8H10	or	C6H5CH2CH3
Isopentane (2-Methylbutane)	C5H12	or	CH3CH(CH3)CH2CH3
Isobutane (2-Methylpropane)	C4H10	or	CH3CH(CH3)CH3
Ethylmethylether (EME)	C4H10O	or	CH3OC2H5
Dimethlyether (DME)	C2H6O	or	CH3OCH3
Methanol	CH4O	or	CH3OH
Ethanol	C2H6O	or	CH3CH2OH
Hydrogen (for comparison)	H2		

The energy per volume in Gj/m of these HRSLs is shown below:

Ammonia	17.35	Octane	33.73	Toluol	26.85
Ethylbenzol	37.30	Isopentane	30.17	Isobutane	27.54
EME	20.34	DME	21.14	Ethanol	23.45
Methanol	17.97	L. Hydrogen	9.93		

91. See explanation of this term in section on Measuring Success.

92. See explanation of this term in section on Measuring Success.

93. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.

94. National Air Toxics Assessment, U.S. EPA, 2006.

95. Data from manufacturer estimates (Caterpillar) and U.S. EPA.

96. Estimate from manufacturer (Lubrizol).

97. See explanation of this term in section on Measuring Success.

98. Part One of the Ohio Climate Road Map, Ohio Environmental Council, 2005, pp. 29-31.