The Bixby Energy Concept

"Making Biomass a usable, economically practical energy source"

Fortune Magazine/August 23rd, 2004

We're more vulnerable now than we were in 1973. Back then the U.S. imported 30% of its oil. Today 60% comes from foreign sources. Much as we might like to, we can't blame it on OPEC. Americans have been on a two-decade oil pig-out, gorging like oversized vacationers at a Vegas buffet. Yes, China is gulping more and more oil. But the U.S. has increased its already world-leading consumption by 20% in just the past decade. And there's every chance it'll get worse.

History

Bixby Energy Systems, Inc. was founded July of 2001, with a plan to harness the vast *energy* potential that exists with Biomass. Since its inception, Bixby has validated its concept of energy production from Biomass, evolved its technology, and is strategically positioned to realize that potential.

Bixby realized that, in the past, the failure to develop Biomass/Waste-To-Energy stemmed from the inability to get the 3 vital factors (a universally usable fuel, a viable energy conversion system to release that energy, and a method of providing the fuel to the end consumer in a regular, consistent manner they could depend on.) working together. Pellets were made that did not burn very well, existing furnaces did not burn this fuel efficiently and new furnaces were not developed to use them, and no system was developed to provide a continuing supply of fuel to the consumers who tried to use them. Bixby reasoned that the solution to these issues would require the planned, simultaneously controlled launching by a single organization would be necessary to insure the successful, cohesive development and implementation of these disciplines. In just 3 years Bixby's accomplishments in achieving those goals are nothing short of revolutionary.

- First, we developed a method of densified pelletization for harvesting the *energy* available in all Biomass materials.
- Second, we developed a burn mechanism for stoves and furnaces with a 99.7% combustion efficiency (twice the ratio of other available burn technologies) producing more potentially usable heat *energy* per pound.
- Third, we established a practical and profitable method of distributing our pelletized fuel products to end consumers.

Bixby has already been acknowledged as an innovator and technology expert in this industry. Our accomplishments have clearly positioned us as a leader in developing Biomass as an *energy* source in the world. As the world becomes more aware of its increasingly tenuous supply of fossil fuels, Bixby's potential as a major player will grow.

Our Original Strategy was simply to make and market Biomass pellets and furnaces; primarily products that would heat your home and water. However, as our knowledge advanced we realized that our potential for expanding the scope of this technology was immense. What follows is a synopsis of these opportunities and what they will mean to the company's overall development.

Validating the Concept

Our Current Focus has been to launch our flagship product, the Bixby Stove, (a 50,000 Btu/hr system) and its ancillary hearth products. Known more popularly as "corn stoves", we developed this design first because it provided the ideal situation for proving the performance of our technology in a market with a large, existing and unfilled demand. We designed it to obtain *energy* from dry shelled corn which is nature's natural biomass pellet and is abundantly available and cheap. This allows us to avoid the heavy financial burden of building a pelletizing plant at this stage of our development.

These products represent our initial thrust into Hearth products retailers. Our Biomass (Corn) Stoves, their related Venting Pipes and Accessories, and our Hearth Pads have been well received by consumers. And, the continued rise in cost of gas and oil will only increase that demand.

Oil & Gas Journal, September 6th, 2004

Bernard J. Picchi, senior managing director of Foresight Research Solutions LLC, New York says "We are very unlikely to return to crude prices of$17-20/bbl." Like many others, he predicted prices will escalate in the next "inevitable" Middle East crisis. "The world must seek other energy sources. This will be the decade of alternative energy development."

Building the Business Structure

The 2005/2006 season will usher in our transition from stove maker to that of an Energy Company. With this phase of our development, we intend to:

- **Complete Our Family of Hearth Products** with a Mini-Stove, a Utility Stove, a Fireplace Insert, Corn Barbecue Grill, and Bixby branded and bagged "Bixby Green" Dry Shelled Corn. This line of product will solidify our position as the leader in Biomass Heating Technology in the stove products industry.

- **Set the Stage for the introduction of our Residential Furnace System.** This furnace (a 125,000 Btu/hr system) will be launched through the HVAC Industry (Heating, Ventilating, & Air Conditioning) and will represent Bixby's transition from a Stove Company to an Energy Company.

- **Compelling Technological Improvement.** Our existing products will evolve with compelling advancements in our technology that will further enhance their potential.

  The introduction of Bixby's *BioComposite Technology* will provide us the opportunity, as early as next year, to replace our steel components with

materials made from Biomass. Adapting this technology will mean a savings over steel costs of as much as 75%, with a weight reduction of 40% or more while simplifying the manufacturing process.

In the future, our residential and commercial furnace systems, using technology already available, will advance to the capability of generating electricity as well. Additional technology being developed will provide furnaces that can either burn our engineered fuel pellets or gasify them, on demand, to provide clean burning methane (natural gas) or hydrogen.

• **Evolving into an *Energy* Company** will require the integral development of the 3 segments we believe are necessary to solidify the future success of the Bixby Concept. We call it the "3 legged stool" approach because each aspect of the concept is supported by the other two. It encompasses:

- The creation of a high tech, high quality Biomass Furnace system
- The building of our first Plant for making Pelleted Fuels
- The planned, focused market development of our Fuel Distribution system through Step Saver. We acquired Step Saver, an established salt distribution firm using trucks designed to "blow" salt into storage units, because it provided us the quickest, most efficient and economical method of delivering energy directly to our customers.

• **The First Leg,** the completion and introduction of The Model 1000 Furnace, a 125,000 Btu/hr System central heating/hot water system for the residential market, will represent the state-of-the-art in Biomass furnace technology. This product will initially be targeted to the rural market already receiving delivery of propane and fuel oil. Our *Multi-Fuel Furnace System* will operate on dry shelled corn, wood pellets, Bixby Engineered Fuel Pellets, as well as Propane or Natural Gas. This high degree of fuel flexibility will ease the assimilation of this technology into the mainstream marketplace.

The Agriculture Industry represents the next logical step for rapidly inculcating our system into a mainstream market. As a start to that endeavor, Bixby is currently working with Jennie-O, the largest turkey grower in the U.S., to define the system that will solve not only their *energy* problems, but their waste issues as well.

The Jennie-O example illustrates the potential of this market segment. They raise their birds in 12,000 barns throughout the U.S. Each of these 60' x 160' buildings use eight 250,000 Btu/hr furnaces and consume 21,000 gallons of propane a year. The turkeys also produce tons of turkey litter (onto wood chip bedding) that must be disposed of. This waste represents a Biomass source of *energy* of approximately 9,000 Btu's/hr per pound. By using Bixby furnaces, Jennie-O can enjoy heating savings of approximately 70%, or *about $19,000 per barn, per season!.* By removing their turkey waste, we relieve them of a problem and gain a valuable source material for

high *energy* fuel. ***Perfect symbiosis!*** And this example represents just one customer in this huge industry of turkey, chicken, duck, veal, lamb, cattle, and hogs who also bring along with their business valuable waste material for fuel.

• **The Second Leg,** the completion of our first Densification Plant, will launch Bixby into the *energy* supply business as a maker/marketer of densified fuel pellets. These engineered, densified fuel pellets will provide consumers with 70% or more in *energy* savings over propane, fuel oil, or electricity. The Bixby process of producing "densified" fuel pellets represents the first sensible method of harnessing the vast *energy* potential of Biomass materials all over the world.

• **The Third Leg** of the Bixby Concept is the distribution of our Fuels to our Furnace users by building the "Step Saver Highway". This will compliment the targeted sale and installation of our furnace systems by strategically planning the guaranteed delivery of our fuel pellets to the customers buying our furnace systems.

• **Bixby will take an aggressive approach** to the development of its *Patent Estate.* We have developed many revolutionary concepts, and are implementing them with real products and technologies that patents have been filed for. We will continue to aggressively file for patent protection on all our intellectual property as we continue to develop these compelling technologies.

Implementation of the National Strategy

• **Licensing: The Next Logical Progression.** The Bixby Concept provides the greatest opportunity for development of the vast potential that exists with Biomass and Waste as all encompassing *energy* sources. However, the market for Bixby's *energy* products is so huge that if Bixby were to limit its development using only the resources available within its own structure, it could possibly take more than 20 years.

To proactively accelerate the development of this potential will require involvement by competent organizations who we can license our turn-key technology to. Licensing fees, if the Bixby Concept is allowed to be fully developed, could eventually represent Billions of dollars yearly in revenue. (Currently, Bixby has engaged a marketing firm to research and determine an accurate estimation of licensing's true financial potential.) Bixby has already been approached about licensing some of the technologies we currently have developed as well as technologies still on the drawing board.

• **Other Technologies at Bixby Energy** to be developed with significant licensing potential. Bixby's technology will allow us to develop:

- A Residential Furnace that also generates your home's electricity
- Central air conditioning systems for residential and commercial applications
- A heating system for the swimming pool industry
- Furnace systems for every commercial application
  - Large Industrial Furnaces
  - Distributed Generation Systems
  - Boiler & Steam Systems
  - Electrical Generation Plants
- Grain Dryers that will use the grains just grown as fuel and eliminate the need to use expensive propane or natural gas; in essence literally growing the grain for drying, simultaneously with the grain being harvested that will require drying.

These are only some of the examples; however, literally every application where *energy* is used today can benefit from the Bixby technology.

The Final Evolution: Our "Conversion-To-Energy" Plants. Ultimately, it is the intent of Bixby to evolve from pelletization to a multi-dimensional process-to-engineered-fuels operation. Our fully developed CTE (Conversion-to-Energy) Facilities will utilize not only Densified Pellitization, but Gasification and Pyrolisis. Gasification is the conversion of materials directly to a gas state (hydrogen or methane). Pyrolisis is the conversion of materials directly to an oil state. These "Super Processing" facilities will have the ability to process, not only agricultural waste, but wood waste, municipal waste, and rubber tires. Using gasification and pyrolitic techniques already developed, (and patented or patent pending) the engineered fuels we produce will expand beyond Densified Pellets to Methane Gas and Hydrogen, and Bio and Hydrocarbon Oil. *What we will have developed is the ultimate system for the complete, practical utilization and conversion of our world's waste resources to energy.*

Each of these technologies compliments the other. For example, Densification and Pelletization need water removed while pyrolisis requires that water be added. The result is a symbiotic system that will provide for the maximum conversion of all materials received into engineered fuels or value added materials.

The Ultimate Payout: A System that Advances Waste Utilization in the world and converts it to energy in an economic and practical way. In its final evolution, Bixby Energy will become a system for receiving the waste of the world (sometimes being paid to take it), and converting it to fuel that we will sell as *energy* directly to the end consumer. Our transportation system will thrive because of the economics of simultaneously delivering energy and retrieving waste. Simply said, Bixby has developed a logical way to profitably provide alternative energy from our vast and quickly renewable waste resources using technology already in existence.

The Opportunity Is Ours for the Taking

Bixby has strategically developed its products, and plan of action to implement a strong, steady, and controlled growth into a leadership position in the world's *Energy* Industry. The way Bixby is harnessing the potential of *energy* from Biomass and Waste, the compelling products it is creating to utilize that *energy*, and the revolutionary methods it has developed to bring this technology to the mainstream marketplace, will forever change the way the world thinks about *energy*.

Newsweek Magazine/September 20th, 2004

"When push comes to shove, energy security will trump all other issues".

Tackling Mercury Emissions in Minnesota

February 23, 2005

Senate Energy, Jobs and Community Development Committee

Sarah Welch,
Associate Director
Midwest Office

Izaak Walton League of America

Roadmap

- **Describe concerns about mercury.**
- Review briefly the science of mercury.
- Review of the Minnesota Mercury Contamination Reduction Initiative.
- Present League analysis of MCRI effectiveness (or lack thereof).
- Introduce ideas for future mercury reduction.

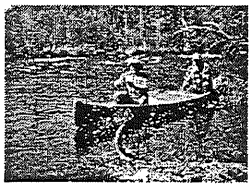
Why are we concerned about mercury?

- MDH has issued a **statewide fish consumption advisory** due to mercury contamination.
- Find fish consumption advice for your favorite lake on DNR website.

Why are we concerned about mercury?

- The U.S. EPA found that one in six **women of childbearing age** have mercury in their bodies at levels that may adversely affect their unborn child. This could affect up to **630,000 newborns** in the U.S. each year.
  - *Mercury is a **potent neurotoxin** that can adversely affect the development of the central nervous system in fetuses and young children.*
  - *Newest research suggests that mercury can also adversely affect **cardiovascular function** in adult men.*

Why are we concerned about mercury?



- Sportfishing in Minnesota has a **$2.8 billion** annual economic impact, according to the American Sportfishing Association. This includes:
  - *retail sales ($1.4 billion)*
  - *salaries and wages ($708 million)*
  - *sales and motor fuel taxes ($103 million)*
  - *state income taxes ($24 million)*
  - *federal income taxes ($114 million).*
- An estimated **25,955 jobs** in Minnesota are also tied to the future of fishing.

The answer to the problem is clearly *not* to fish less!

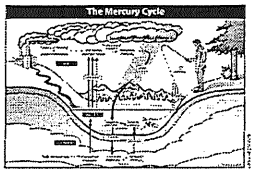
Roadmap

- Describe concerns about mercury.
- **Review briefly the science of mercury.**
- Review of the Minnesota Mercury Contamination Reduction Initiative.
- Present League analysis of MCRI effectiveness (or lack thereof).
- Introduce ideas for future mercury reduction.

What is mercury?

- Mercury (Hg) is a naturally occurring element in the earth's crust.
- Coal – which we dig up and burn to produce 75% of our electricity in Minnesota – contains Hg.
- Hg never degrades or breaks down in the environment.
- 2/3 of Hg currently circulating in the environment has been released by human activities – notably, burning fossil fuels.

The Mercury Cycle



- Hg is emitted into the air when we burn fossil fuels.
- Hg falls back to Earth through precipitation.
- Bacteria in aquatic ecosystems convert it to methylmercury.
- Fish absorb methylmercury from the water directly and from eating other organisms.
- Methylmercury concentrates up the food chain as larger fish eat smaller fish.
- Walleye, northern pike, and bass usually have the highest concentrations of methylmercury.
- Humans, birds and other wildlife that eat fish are exposed to methylmercury by eating contaminated fish.

Roadmap

- Describe concerns about mercury.
- Review briefly the science of mercury.
- **Review of the Minnesota Mercury Contamination Reduction Initiative.**
- Present League analysis of MCRI effectiveness (or lack thereof).
- Introduce ideas for future mercury reduction.

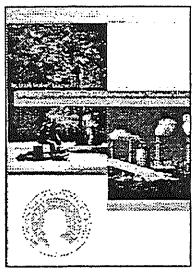
The Mercury Contamination Reduction Initiative (MCRI)

- An Advisory Council began meeting in 1997 to address the mercury contamination problem.
  - *Council comprised of industry representatives, government agencies and environmental organizations (see Appendix I)*
  - *Recommended up to 1,500 lbs/yr Hg reduction*
- In 1999 Minn. Stat. §116.915 established the MCRI with voluntary reduction targets of:
  - *60% reduction from 1990 levels by 2000*
  - *70% reduction from 1990 levels by 2005*
- MPCA must submit a final report to the Legislature on MCRI results in October 2005.
- To date, MPCA and others claim we are on track to meet the voluntary reduction goals.

Roadmap

- Describe concerns about mercury.
- Review briefly the science of mercury.
- Review of the Minnesota Mercury Contamination Reduction Initiative.
- **Present League analysis of MCRI effectiveness (or lack thereof).**
- Introduce ideas for future mercury reduction.

League analysis: *Reducing Mercury Pollution* report



- Re ductions occurred.
- M CRI not responsible for the reductions.
- Ca lls into question efficacy of voluntary programs.

League Analysis

- League commends the mercury reductions that occurred in the period 1990-2000.
- League analysis demonstrates that most of the reductions:
  - *Resulted from state and federal mandates, not voluntary action*
  - *Resulted from other initiatives, not the MCRI*
  - *Resulted almost exclusively from one sector*
- We will need to increase the level of reductions in the future.
  - *Growing demand for electricity*
  - *New power plant proposals*

Reductions Were Not Voluntary

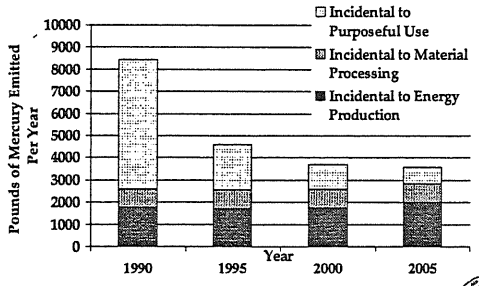
- *Federal regulations set in 1990s for waste combustors and wastewater dischargers*
- *In 1990s, Minnesota banned meraury-containing products including:*
  - *Batteries*
  - *Inks*
  - *Pigments*
  - *Dyes*
  - *Fungicides*
  - *Toys and games*
  - *Apparel*
  - *Thermometers (2001)*

See IWLA. Appendix III

MCRI Played Minimal Role

- MCRI cannot be credited with the reductions achieved prior to its passage in 1999.
- Current data shows few MCRI-related reductions have occurred since 1999.

Reductions Were Not from All Sectors



Source: Minnesota Pollution Control Agency, September 2001.

Giving Reductions Context

The Advisory Council recommended that up to **1,500 lb/yr** could be reduced voluntarily from sources in Minnesota.

Facility	Air Emissions Reductions resulting from the MCRI, based on voluntary agreements	Comparison to MPCA 2000 Minnesota Mercury Inventory Emissions
Xcel Energy	Up to 35 pounds	Sherco – 886 pounds
Minnesota Power	Up to 57 pounds	Boswell – 263 pounds
North Star Steel	2 pounds	176 pounds

MCRI Not Designed to Succeed

- The Advisory Council members, "...insisted that there should be no state mandates. No firm should be forced to:
  - (a) develop a voluntary agreement,
  - (b) follow agreement reporting standards or schedules,
  - (c) include in its voluntary agreement any terms specified by the state,
  - (d) meet data collection, maintenance, or reporting requirements, and
  - (e) incur penalties for not developing a voluntary agreement according to state guidelines."

Roadmap

- Describe concerns about mercury.
- Review briefly the science of mercury.
- Review of the Minnesota Mercury Contamination Reduction Initiative.
- Present League analysis of MCRI effectiveness (or lack thereof).
- **Introduce ideas for future mercury reduction.**

Lessons Learned: Designs for Success

- Set industry- or sector-specific goals
- Focus on mercury emitted directly into the air:
  - *MPCA estimates that about 15% of mercury contained in products makes it to the atmosphere*
  - *100% of mercury emissions from utility and industrial smokestacks makes it to the atmosphere*
- Focus on largest emitters
  - *Electric utilities and taconite are responsible for 2/3 of emissions*
- Provide industry with both "carrots" and "sticks"

A Success Story

- Emissions reduction rider – Minn. Stat. 216B.1692 – provides "carrot"
- Xcel Energy's Metro Emissions Reduction Project (MERP)
  - This project will result in a reduction of ≈ 170 pounds of mercury from the King, High Bridge and Riverside plants combined.
  - Reductions will occur in the 2006-2009 time frame and are not related to the MCRI.

Coming Soon: Federal Regulation?

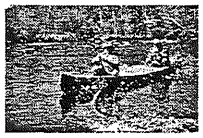
- U.S. EPA to finalize proposed rule regulating mercury emissions from electric generating units in March.
- The rule is not likely to affect Minnesota plants.
  - In her comments on the rule, MPCA Commissioner Corrigan stated: *"The Maximum Achievable Control Technology (MACT) standard and the cap levels proposed in the rule will not likely result in significant mercury reductions from power plants in and upwind of Minnesota."*

Future Policy Goals for Minnesota

- Require all electric utility units greater than 25 MW to reduce mercury emissions 90% by 2009
  - Units employing wet scrubbers could have additional time to meet the reduction goals given that reduction technology may still be in development.
- Extend the sunset date of the emissions reduction rider statute from 2006 to 2009 (Minn Stat. 216B.1692)
- Require taconite industry to invest in research and development of mercury control technologies.
- Require the MPCA to report sector-specific reduction progress in the 2005 MCRI report to the legislature.

Why Mercury Matters: Clean Water, Safe Fish, Healthy Kids





Resources

Mercury-Free Minnesota
www.mercuryfreeminnesota.org

Minnesota Environmental Partnership
www.mepartnership.org

Izaak Walton League of America
www.iwla.org/cleanair/mercury.html

Dept of Health Fish Consumption Advice
www.health.state.mn.us/divs/eh/fish/index.html

Dept of Natural Resources Lake Finder
www.dnr.state.mn.us/lakefind/index.html

Minnesota Pollution Control Agency
www.pca.state.mn.us/mercury

U.S. Environmental Protection Agency
www.epa.gov/mercury

CLSA
ASIA-PACIFIC MARKETS

Solar power

Sector outlook

Michael Rogol
michael.rogol@clsa.com
(1) 6268181299

Shintaro Doi
shintaro.doi@clsa.com

Anthony Wilkinson
anthony.wilkinson@clsa.com

July 2004

Japan
Energy/Technology

Priority investment ideas

Sekisui Chemical (4204JP)
Tokuyama (4043JP)
Evergreen Solar (ESLR)
SolarWorld (SWV GR)
Sharp (6753JP)
Kyocera (6971JP)
Q Cells (IPO)

Other solar plays

Panahome (1924JP)
SxL (1919JP)
Fujipream (4237JP)
Kubota (6326JP)
Omron (6645JP)
E-Ton (IPO)
PV Crystalox (IPO)
Thai Solartron (IPO)

Contents

Just these sections included here

Sun screen

In recent months alternative energy has attracted much attention. Lost in the noise has been a deeper, fundamental story about solar power's transition to a fast-growth, profitable industry. With a market of US$7bn growing >30% pa and expanding profit margins, solar power will increasingly drive shareholder value for numerous companies. We advise investors in energy and electronics and thematic investors to become familiar with this sector, to evaluate specific investment opportunities, and to keep a watch for upcoming IPOs.

Investment opportunities in solar power

This US$7bn industry has realistic potential to achieve US$30bn in 2010

Solar power is hot. This year the sector will grow >40% with customer demand so high that many vendors are already "sold out" until early 2006 (excl "strategic customers") and >30% growth is expected through at least 2010. More importantly, many companies in the sector are achieving profits for the first time this year and margins will continue expanding through 2007 driven by >5% annual cost reductions. The result is that the solar power market has realistic potential to expand from US$7bn in 2004 to US$30bn in 2010, with the industry's profit pool expanding from US$0.8bn to US$3bn.

We screened more than 200 companies . . .

We reviewed >200 solar players along the solar supply chain, met with >50, and analyzed 15 for revenue, profit, and growth potential. This may be the broadest analysis of solar power ever conducted with a focus on equity investment. The overall result: solar is an attractive sector for energy, electronics and theme investors, with greatest value-creation from raw silicon feedstock price increases, adoption of lower-cost manufacturing processes, and integration of solar power into new applications (buildings/roofing).

. . . and identified 15 specific investment opportunities

We have identified 15 top solar investment opportunities. These include solar installers with strong revenue & earnings growth – **Sekisui Chemical** (4204JP), **Fujipream** (4237JP), **SxL** (1919JP), **Panahome** (1924JP), **Kubota** (6326JP); silicon suppliers whose margins expand as silicon prices rise through 2007 – **Tokuyama** (4043JP); pure plays who could see exponential stock price growth based on rapid expansion plans — **Evergreen Solar** (ESLR), **SolarWorld** (SWV GR), **Q Cells** (IPO); undervalued big companies for whom solar will deliver >10% of 2010 OP – **Sharp** (6753JP), **Kyocera** (6971JP), **Omron** (6645JP); and IPOs for several companies – **E-Ton, PV Crystolox, Thai Solatron.**

Rising interest rates and negative utility reaction are the biggest risks to solar power

The biggest risk to solar stocks comes from higher interest rates. A three-five percentage point increase in interest rates could significantly disrupt demand. In addition, solar power has potential in the longer term to reduce profits of large utilities in Germany (**RWE, EON**) and Japan (**Tepco, Kansai Electric**). If this happens, utilities may oppose solar's expansion. In our view, these risks are mitigated by passionate support at the grassroots and in government that ensures continuing incentives in many markets. With demand surging, costs falling, and public support continuing, we believe solar will continue to shine.

Outlook for solar power sector

	2003	04CL	05CL	06CL	07CL	08CL	09CL	10CL
Demand (GW)	0.7	1.0	1.4	1.9	2.4	3.2	4.1	5.3
Demand growth (% increase in MW)	0	40	38	35	30	30	30	30
Average installed price (US$/W)	7.0	7.1	7.0	6.8	6.5	6.2	5.8	5.5
Revenue pool (US$bn)	5	7	10	13	16	19	24	30
Industry avg. operating margin (%)	8	11	13	14	14	13	12	11
Operating profit pool (US$bn)	0.4	0.8	1.2	1.8	2.3	2.6	3.0	3.3

Source: CLSA Asia-Pacific Markets

Solar power – A quick introduction

- Solar power is the conversion of sunlight into electricity.
- The main feedstock of the solar power industry is silicon made into cells about the size of a compact disk, collected into poster size modules.
- A typical on-grid solar power system includes modules, inverters & other components.
- A typical system is 3-4kW DC (25 modules) on a residential rooftop in Japan/Germany (i.e. decentralized residential installation).
- Cost of a typical installation is US$20-25,000, often financed with a loan.
- To a lesser extent, solar power is also used in remote regions without access to the grid, in larger centralized systems, and in electronics.
- Solar power has grown >30% pa since 1990 and has US$7bn in revenue.

Schematic overview of solar power sector[1]

INVESTMENT OPPORTUNITES		
Tokuyama (4043 JP)	**Silicon (US$0.5bn)**	❑ Process quartz to create electronics - grade silicon or slightly less pure solar - grade silicon
PV Crystolox (IPO) **SolarWorld** (SWV GR)	**Ingot and wafers (US$0.9bn)**	❑ Raw solar - silicon melted and shaped into ingots ❑ Ingots are then cut/blocked & sliced into wafers
Q Cells (IPO)	**Solar cells (US$1.7bn)**	❑ Electrical field across junction of positive and negative layers creates electricity when photons of light are absorbed
Sharp (6753 JP) **Kyocera** (6971 JP) **Evergreen Solar** (ESLR) **E-Ton** (IPO) **Thai Solartron** (IPO)	**Solar modules (US$3bn)**	❑ "Stringing" of cells connected to form larger circuit panel ❑ Panel is framed with aluminum, covered with glass (both protection and support) and backed with laminate & electrical connections
Omron (6645 JP) **Kyocera** (6971 JP)	**System components (US$1bn)**	❑ Several components added to make system ❑ Inverters change DC to AC (15-25% loss) ❑ Batteries are expensive, so rarely installed ❑ Other components include wiring and mounting
Sekisui Chemical (4204 JP) **Fujipream** (4237 JP) **SxL** (6326 JP) **Kubota** (6326 JP) **Panahome** (1924 JP)	**Installation and services (US$7bn)**	❑ Most installations are buildings connected to grid but some MW-scale plants & remote systems too ❑ Most installations are debt financed ❑ Services include loans, incentive program processing fees, customer system design, etc
	Government and incentives ($1 bn)	❑ Governments in largest solar markets provide incentives for end-customer adoption ❑ In Japan (the largest market), the govt pays ~US$500/kW ❑ In Germany, utilities buy solar electricity at US$0.70/kWh (avg grid price of US$0.17)

[1] Estimate of gross spending within each sector of supply chain in parentheses. Solar power processes and technologies are diverse. This Figure presents an overview; Estimates of gross spending (e.g. US$7bn paid to installers for solar installations & services, US$3bn paid to module companies for solar modules) at different stages of supply chain. Total industry net revenue (accounting for inter-segment sales) of US$7bn; Segment spending is not additive. Please note that "solar power" does not include "solar thermal" systems that warm water with sunlight. Please also note that estimates do not include capital expenditures on manufacturing equipment. Source: CLSA Asia-Pacific Markets

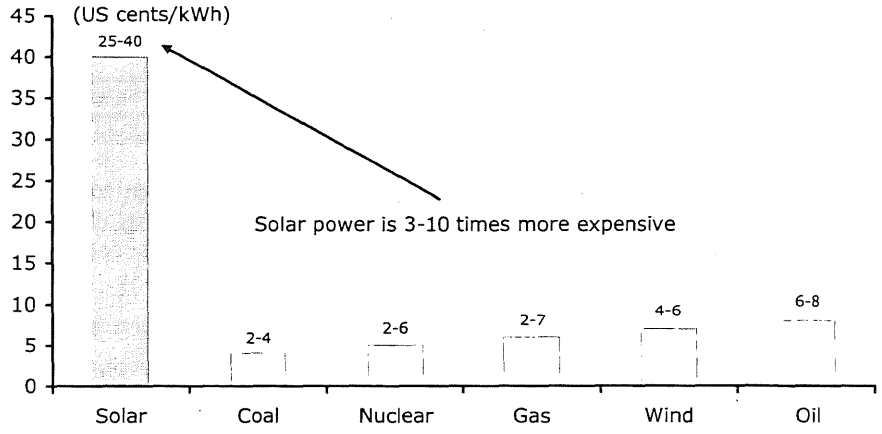
Sun rising for solar

"Here comes the sun and I say it's all right"
George Harrison

Why would anyone invest in solar power? Since its first laboratory applications in the 1954, solar power has been the source of hype followed by disappointment. There are numerous reasons why investors have shied away from this sector. Perhaps most damning, the levelised solar power generating cost – US25-40¢ per kilowatt-hour (kWh) depending on system cost and hours of sunlight – is multiples higher than other sources of power. Yet even a quick look at this sector's 23x growth over the last decade (see Figure 2) suggests that **there is more to the story**.

Figure 1

Typical range of fully-loaded generating cost

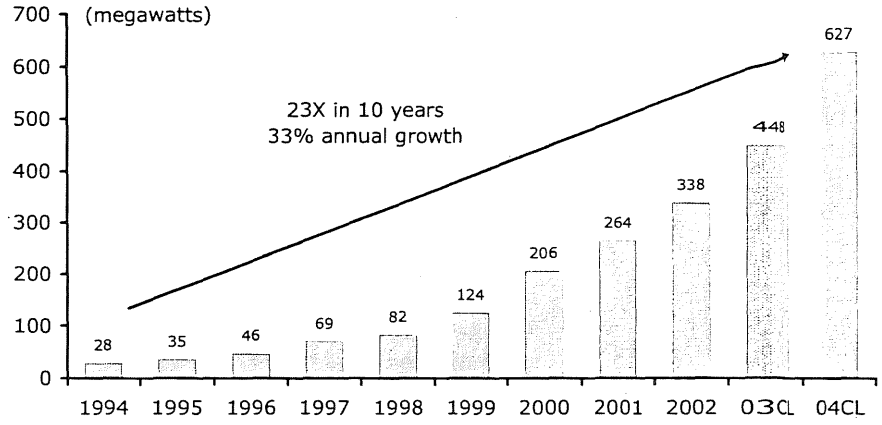


Note: rough range of typical costs. Source: CLSA Asia-Pacific Markets

Solar power grew 23x over the last decade

Figure 2

Annual installations of solar power in OECD



Note: 1GW of solar power expected to be sold in 2004. 627MW expected to be installed during year in OECD countries. Remaining 373MW are either part of supply chain at year end (e.g. inventories and product in process of being shipped to customers) or are installed during year in non-OECD counties. Source: CLSA Asia-Pacific Markets, IEA PVPS

Overcoming our incorrect impressions of solar

We were initially sceptical, but this sector has a realistic chance to grow to USUS$30bn by 2010

Initially sceptical, we have become enthusiastic about solar power because it has realistic prospects for revenue to expand from US$7bn to US$30bn by 2010, for sector operating profit to increase from >US$0.7bn to >US$3bn, and for significant growth in the stock market.

Figure 3

Outlook for solar power sector[1]

	2003	2004	2005	2006	2007	2008	2009	2010
Demand (gigawatt)	0.7	1.0	1.4	1.9	2.4	3.2	4.1	5.3
Demand growth (% increase in MW)	0	40	38	35	30	30	30	30
Average installed price (US$/watt)	7.0	7.1	7.0	6.8	6.5	6.2	5.8	5.5
Revenue pool (US$bn)	5	7	10	13	16	19	24	30
Industry avg. operating margin (%)	8	11	13	14	14	13	12	11
Operating profit pool (US$bn)	0.4	0.8	1.2	1.8	2.3	2.6	3.0	3.3

[1] Estimates based on >60 interviews with solar industry executives, government officials, and customers. Average prices are higher than typical prices due to higher-price small wattage modules, higher price installations (often in more remote areas), customer design services, processing fees in some markets, use of additional components (e.g. batteries) in small percentage of installations. Source: CLSA Asia-Pacific Markets

Five fundamental views on the sector that were not intuitive for us

So what converted our scepticism to excitement? Basically, we learned that our initial views of the sector were often wrong. Along the way, we developed five fundamental views on this sector that are quite different than our perspective a year ago:

1. Solar power competes with grid *prices* not generator *costs*
2. Cost-reductions of >5%/year are realistic
3. Innovations in manufacturing are more important than those in the laboratories
4. For investors, solar is much more attractive than wind power
5. In many markets solar power is the economic power choice for customers

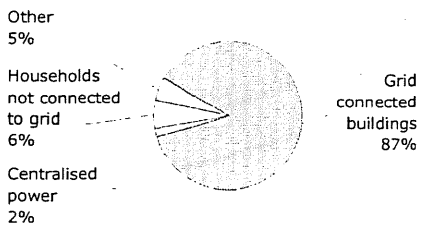
1. Solar power competes with grid prices not generation costs

Per Figure 1, it is clear that the cost of generating power from solar is 3 to 10 times more expensive than the cost of generating from other sources. But this comparison is irrelevant because solar power does not normally compete with the generating cost of other power sources. Most solar power installations are for grid-connected residential/commercial buildings in OECD countries. These installations compete with the retail price of power which includes generating costs, transmission & distribution costs, taxes, profits, and other fees. As such, *solar competes with end-user prices which are much higher than generation costs*. Japan – the world's highest priced large market for power – has average residential power prices of US25 cents per kWh. This is quite important because competing against a grid price of US25 cents/kWh is multiples easier than competing against fossil/nuclear/wind generation costs of US2-8 cents/kWh.

Most solar power is in the OECD and connected to the grid, so it competes with grid prices

Figure 4

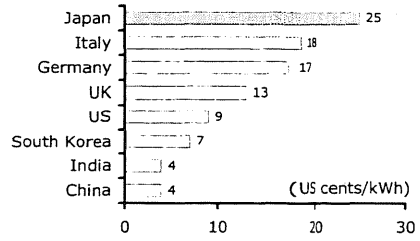
Solar power installation by type



Source: IEA PVPS 2002, CLSA Asia-Pacific Markets

Figure 5

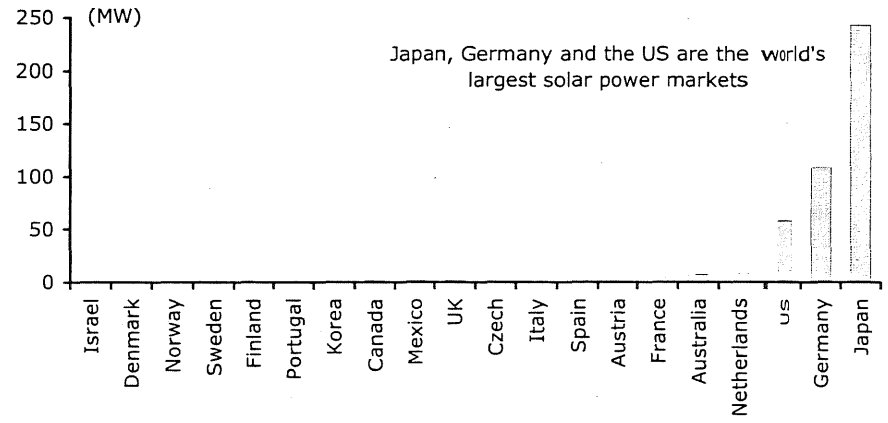
Ave residential power price



Source: US EIA, CLSA Asia-Pacific Markets

Figure 6

Annual PV installations by country in 2003



Source: MIT Laboratory for Energy & Environment estimate of 2003 annual installations based on 2002 IEA PVPS data.

Significant cost reductions will continue

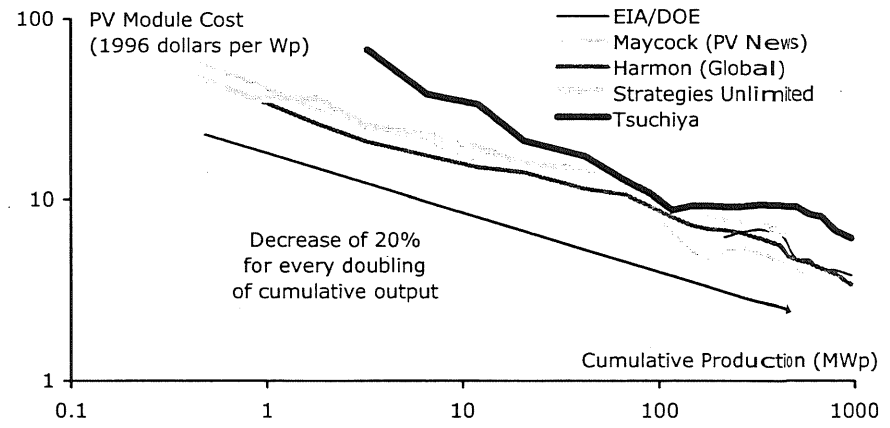
2. Cost reduction of >5%/year

Two years ago, we viewed solar power as a mature technology with slim prospects for significant cost reductions because companies had been working on solar for decades. However, this view ignored the learning gained by solar manufacturers as they have gained scale and experience. Several experts have assessed the value of this learning and come up with consistent estimates that the *cost of producing photovoltaic modules decreases by ~20% for every cumulative doubling of output*. This means that as cumulative output of the industry went from 1 to 2GW, the cost of manufacturing a single watt fell by 20%. With market growth of >30% per year over the last decade, this has translated into >5% annual cost reductions. Based on company interviews and plant tours, there is *strong consensus that module cost reductions will continue at least 5%/year through the end of the decade*, with potential for even stronger cost reductions. Similar cost reductions are expected for the rest of the solar-power system (including inverters, other components, and installation).

Costs decrease by 20% every time cumulative output for the industry doubles

Figure 7

Solar power module cost versus cumulative output

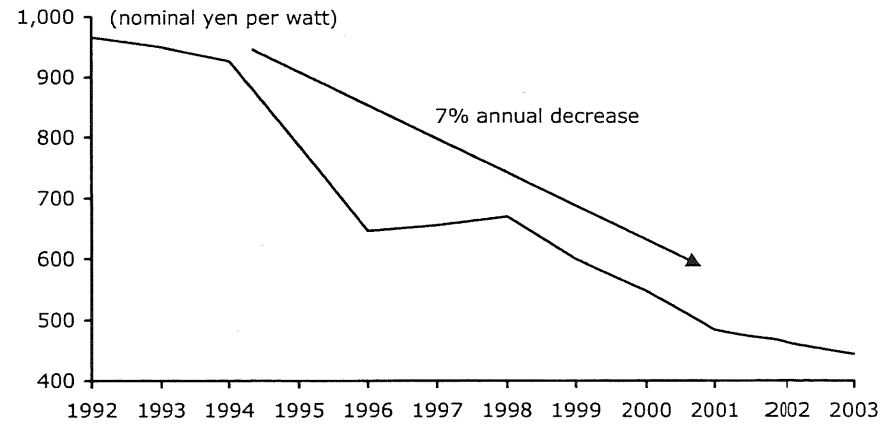


Source: Robert Margolis; Cambridge Energy Research Associates courtesy of Steve Taub

In the world's largest market, prices have decreased 7+%/year

Figure 8

Estimate of average module prices in Japan



Source: CLSA Asia-Pacific Markets; IEA PVPS

Incremental manufacturing improvements will drive >5% cost reductions

3. Manufacturing is more important than R&D breakthroughs

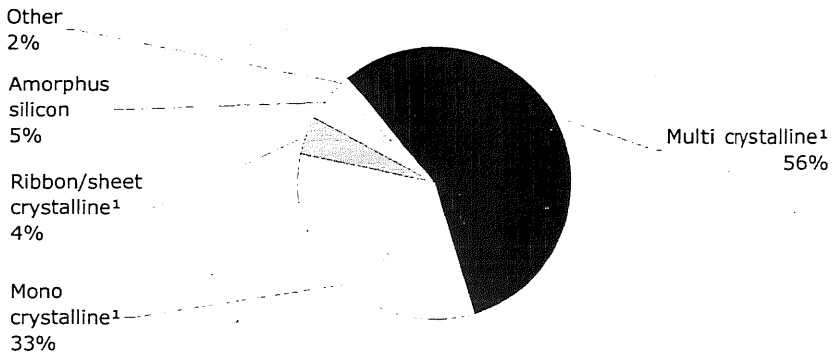
When we initially looked at the solar sector, we expected breakthroughs in R&D to be the key driver of cost and performance improvements. While innovation is important, manufacturing process improvement is the main driver of reducing costs. There have been numerous laboratory innovations – including solar cells with efficiencies of >30% compared with commercial cells averaging ~15% - but nearly all of these innovations fail to reach commercial viability. As a top solar scientist said in an interview, "The pipeline of research breakthroughs is huge, but the real challenge for the industry isn't in the labs, it's on the plant floor. There is *so much more we can do to improve economics by improving our manufacturing systems. Manufacturing process is the key for this industry for the next 10 years.*" This is the reason that PV manufacturers have focused increasingly on a narrow range of technologies – mainly crystalline photovoltaics – over the last decade. This trend is expected to continue, with manufacturers and researchers agreeing that crystalline module manufacturing costs (not including overhead, marketing, etc.) are likely to decrease more than 25% by 2010 (from ~US$2/W today to under

US$1.50/W). Specifically, we expect non-silicon operating costs to fall an average of 5% per year and for cell efficiency improvements to enable ~4% less silicon/watt each year (about ½kg/year reduction).

Crystalline technologies dominate solar power

Figure 9

Solar power market share by technology



¹ Crystalline technologies. Note: Monocrystalline or single crystal technology are cut from a silicon boule that is grown from a single crystal, in other words a crystal that has grown in only one plane or one direction. Single crystalline are more expensive to manufacture and typically have a slightly higher efficiency than do conventional multicrystalline cells resulting in smaller individual cells and thus typically a slightly smaller module. Solar cells that are created from multicrystalline technology are cut from a silicon boule that is grown from multifaceted crystalline material, or a crystal that grows in multiple directions. Conventional multicrystalline solar cells typically have a slightly lower efficiency resulting in larger individual cells and thus typically a slightly larger module. Source: Photon International for data, Partsonsale for description of mono/multicrystalline.

Figure 10

Key drivers of crystalline module cost reductions¹

Driver of cost savings	Description
Economies of scale	Gains in purchasing, efficiency improvements and reduction of overall breakage/downtime due to economies of scale (often >3 cents/watt/year for largest players)
Module efficiency improvements	Slow but steady reduction of ~1/2 kilogram of silicon per watt each year as module efficiency increases and wafers get thinner (1-2 cents/watt/year in cost savings).
Lower cost materials	Shifts to lower cost materials for stringing, framing, backing, and packaging (1-2 cents/watt/year)
Lower depreciation	Lower depreciation expenses with lower capital costs for manufacturing equipment (varies by company and by accounting standards; often >2 cents/watt difference depreciation expense for new, lower cost/watt manufacturing equipment and previously purchased equipment)
Lower wages	Move to lower wage locations such as China or India (cost reduction >2 cents/watt for some manufacturers)
Narrower range of technologies/customers	Standardization of process by focussing on narrow range of technology (e.g. "we want to be the lowest cost producer of multi crystalline cells anywhere in the world") or focussing on specific customers when manufacturing/delivery logistics are easier

¹ Manufacturing cost of modules is ~US$2.00/watt. 5% cost savings is approximately US$0.10/year. CEOs of five solar cell/module companies reviewed this table. All said that these cost saving estimates are a minimum and that higher cost savings are likely to be achieved.
Source: CLSA Asia-Pacific Markets

Wind market less attractive than solar for investors

4. Solar power more attractive for investors than wind.

Many people dismiss solar and other renewables because they rely heavily on subsidies. But if concerns about climate change do not abate, it seems realistic to expect governments to continue adopting stronger policies to reduce climate change risks. With these policies, renewable energy should

continue growing quickly. While it is widely recognized that wind is much larger in wattage and much lower in cost, it surprises many people to learn that solar power revenues are nearly equal in size to revenues for wind power capacity – US$7bn for solar and US$8bn for wind. Further, solar is much more profitable and is growing much faster.[1] In addition, wind power faces choppy legislative support and opposition to new installations in key geographic markets. In contrast, solar power has enjoyed steadier policies in its major markets and has not faced any significant installation opposition (at least not yet). All in all, it now appears that solar power – a US$7bn sector with expanding profit margins and consistently strong government support in many markets – is more attractive than originally assumed.

Wind capacity is much larger and costs are much lower . . .

Figure 11
Annual installations of solar vs wind

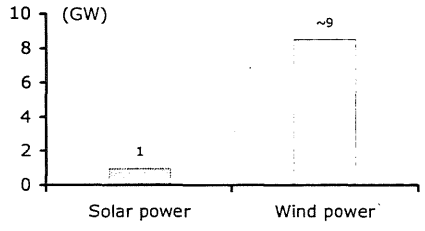
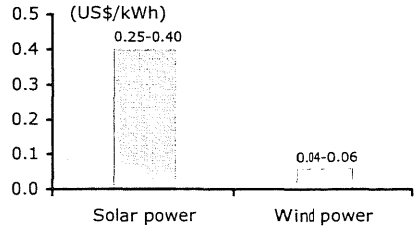


Figure 12
Levelised cost of solar vs wind



Source: CLSA Asia-Pacific Markets; Wind Energy Association

. . . but solar power captures more profit from similar revenue

Figure 13
Revenue from capacity sales

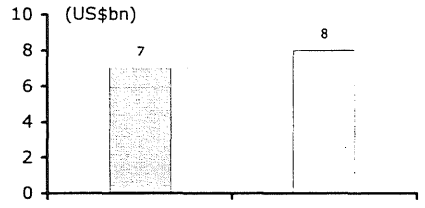
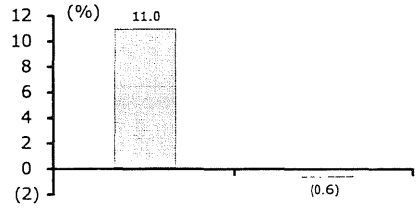


Figure 14
2004 average operating margin[1]



[1] Estimate of average wind power operating margin based on pure-play wind companies that are publicly listed, accounting for ~40% of global sales in 2004. Source: CLSA Asia-Pacific Markets; Cambridge Energy Research Associates

5. Solar power is economic for end customers in many markets

With incentives, solar power is competitive with grid prices in many markets

Japan and Germany are the world's two largest solar markets, accounting for nearly half of annual installations and of total global installed solar power capacity. In both markets, the levelised price of solar power is competitive with the residential grid power price. This is due to government incentives for end-user adoption. In Germany, the government instituted buyback rates for solar power of US$0.69/kWh compared with normal grid rates of US$0.17kWh. This law guarantees this tariff for 20 years, with 5% annual decreases in the buyback rate.[2] In Japan, the national government provides payouts to individual households that purchase solar systems of ~US$500/kW (~7% of total installed system cost) and banks offer consumer loans/mortgages with 1-2% point reduction for solar homes. Incentives exist

The world's largest solar market is removing incentives and demand will still grow 30%/year

[1] These estimates are for capacity (MW) sales not for electricity (MWh) sales. It is worth noting that total cash expenditures for solar power capacity are larger than total cash expenditures on wind capacity if capex for solar and wind manufacturing equipment were to be included.

[2] This means that the buy back rate for a system depends on the year in which it was installed. For example a small home system installed will received US$0.69/kWh for every kilowatt-hour generated for the next 20 years. A system installed next year, will receive 5% less for every kilowatt-hour.

or are emerging in *numerous* other markets (including Spain, Italy, UK, California, New Jersey, New York, and South Korea) that make solar competitive with grid power prices. Our initial reaction to solar's dependence on incentives was to discount the potential of solar power. Our view has changed as we became more convinced that incentives result from perceived global climate change risks and energy security/price concerns that are unlikely to disappear anytime soon. In addition, cost improvements in the solar sector and price increases for grid power enable solar to be more competitive each year regardless of incentives. This is already happening in Japan, where government incentives for residential installations were cut in half this year and will be eliminated by 2006. Despite the reduction in government support, all of >25 Japanese solar companies interviewed believe that the domestic Japanese solar market will continue to grow >30%/year through 2010. Our visits to solar retailers, installers, and customers support this strong growth outlook. In short, Japan appears to have successfully supported the growth of its PV market with incentives and is now in the process of removing those incentives without disrupting market growth.

So, in many markets, solar is competitive with grid prices after public & private incentives:

Figure 15

Grid price versus levelised solar power cost in select markets (US¢/kWh)[1]

	Typical cost of solar without incentives	Typical cost of solar with govt (national & local) incentives	Solar power with government and corporate/bank incentives	Grid power price	Solar competitive with grid price?
Germany	50	(-17)	(-20)	17	Yes
Spain	30	25-30	(-20)	7	Yes
New Jersey	50	45	11	12	Yes
California	35	10-15	10-15	15	Yes
Japan	50	45	20-40	25	Sometimes

[1] Illustrative examples of typical installations, costs ranges, and amount of sun in each market. Negative numbers indicate that customer (e.g. Germany and Spain) indicate that customer is receiving net payment for every kWh generated. Assumptions: Grid prices based on EIA, IEA and national government data for grid prices; assumes current currency conversion rates. Most recent year of data used (varies by country) grid price in local currency. Solar cost assumes typical interest rates and installation cost for each market (e.g. average NEF installation price in Japan). Government incentives vary by market. They include national-level refunds, buy-back rates, low-interest loans, etc. Corporate incentives are most often reduced rate loans from banks trying to acquire retail customers. For example, Japan assumes a 1% point reduction in mortgage for homes with solar systems (1-2% point reductions offered by private banks to attract residential customers). Source: CLSA Asia-Pacific Markets.

Key findings from >50 interviews in last two months

Perhaps "the single broadest effort *ever*"

Taken together, the five points above suggested that solar was well worth a deeper look. So, for the last two months, we have literally flown around the world twice to meet the solar-power players in the world's three largest markets (Japan, Germany, US), tour manufacturing plants, and meet leading researchers. The purpose of these meetings was to refine our views on the sector, and identify attractive equity investment opportunities. According to one senior interviewee, this is "the single broadest effort *ever* for an equity analyst to understand the solar sector."

Based on our interviews, we have developed a financial perspective on solar power that includes quantitative estimates for this sector's revenue and profit pools, its profit margins, and its key profit growth areas. The five most important points are:

Five key points

1. Solar industry to grow from US$7bn to US$30bn by 2010
2. Many solar companies turning from red to profitability this year
3. Industry average margins expanding from 11% this year to 14% in 2007

4. Solar silicon price hike of 50% this year being passed to customers
5. Conservative capex decisions make tech revolution unlikely before 2010

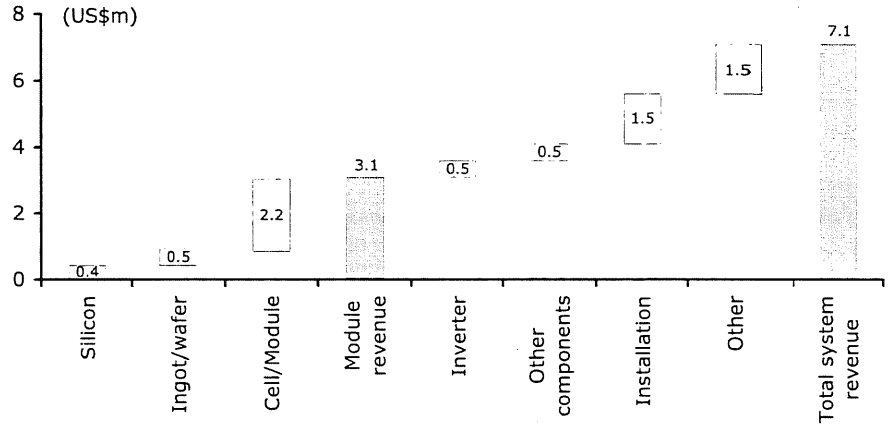
1. Solar industry likely to grow from US$7bn to US$30bn in 2010

At a recent solar industry tradeshow, nearly all of the vendors said that global demand will grow >40% this year and that global growth will continue at >30% through 2010. This is consistent with our interviews in Japan, Germany and the US. Senior executives in the industry say that this is "the best solar market" they have ever seen and most expect the strength to continue until at least 2007. As a result, the solar market could realistically grow from US$7bn this year to US$30bn in 2010.

Revenues in solar power sector are approximately US$7bn this year

Figure 16

Rough estimate of 2004 global solar power revenue pool[1]

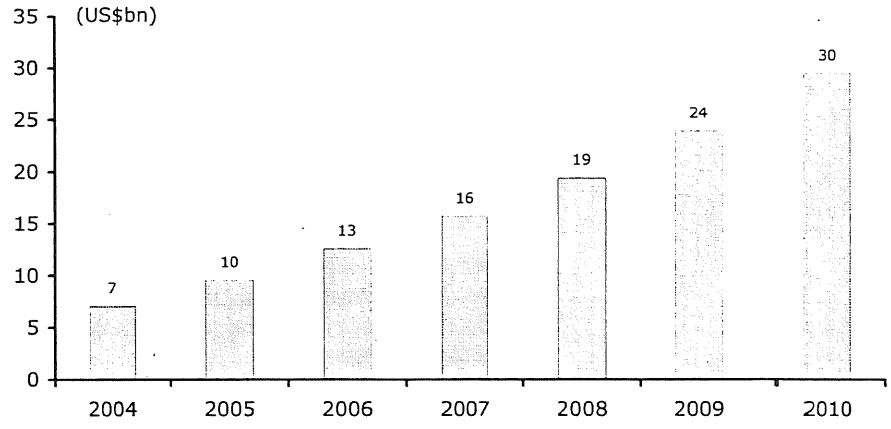


[1] This is an estimate of total industry revenue assuming 1GW of sales in 2004. Average prices are often higher than typical prices. Eg, typical prices in the German market are c. US$0.40 for silicon, US$0.50 for wafers, US$1.7 for cells, US$2.9 for modules, US$0.4 for inverters, US$0.2 for other components, US$0.4 for installation/labor, and US$0.5 for other (transport, processing, fees, etc.). Average prices are higher than typical prices due to small percentage of atypical higher price sales (e.g. batteries, remote locations, custom designs, small wattage modules). "Other" includes fees for processing applications (incentives, loans, etc.), customer design, extraordinary shipping, etc. Source: CLSA Asia-Pacific Markets

By 2010, there is realistic potential for US$30bn in solar power system sales

Figure 17

Rough estimate of global solar power market size[1]



[1] This is an estimate. Please see note on Figure 16. Source: CLSA Asia-Pacific Markets

2. Solar power industry is now profitable

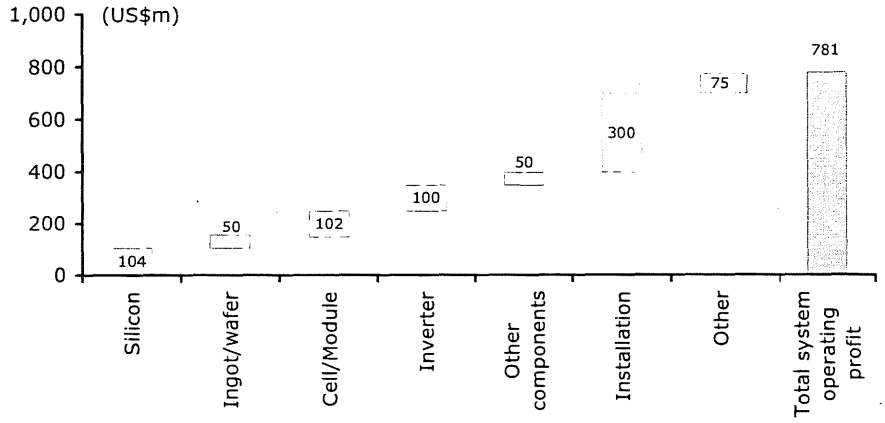
Profits have turned positive and margins will continue expanding

Over the last six quarters many players have turned red ink to black. This is true for all of the largest Japanese module makers (Sharp, Sanyo, Kyocera, Mitsubishi Electric) whose quarterly OP entered positive territory in 2H03, and whose 2004 (FY05 on Japanese calendar) operating margins are expected to range from 2-10%. This is also true for the biggest Europeans (BP and Shell) who have turned profitable this year, and for several smaller German and US players whose profitability is on the rise. It is worth noting that evaluating profitability in the solar power sector is difficult because: many of the largest players are subsidiaries of larger companies who do not publicly release detailed financials on their solar subsidiaries; and many players are private companies who do not publicly release detailed financial results. As such, all discussion of profitability in this paper for non-listed companies and subsidiaries should be viewed as rough estimates based on informal interviews.

Solar power's >US$700m profit pool is growing quickly

Figure 18

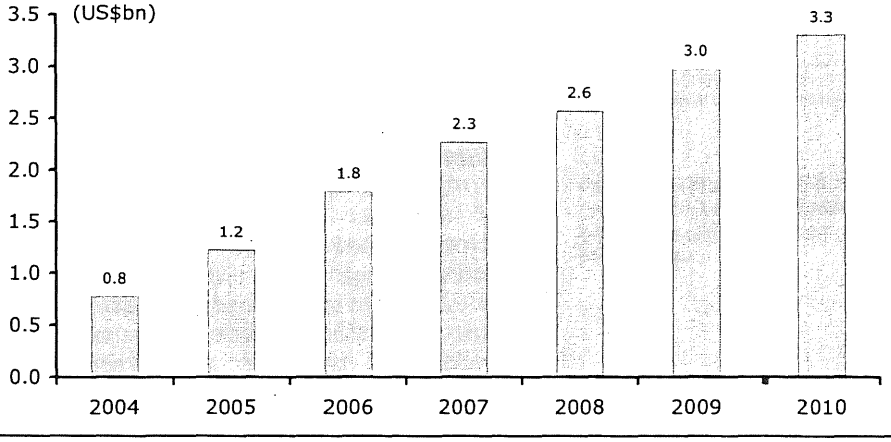
Estimate of 2004 solar power profit pool[1]



[1] Estimate based on informal interviews and outside-in calculations. See note on Figure 16. Estimates are net of profitable and unprofitable companies. Estimate of "other" may be significantly lower than actual; an OP range for "other" of US$75-300m appears realistic from preliminary interviews, but requires additional research. Source: CLSA Asia-Pacific Markets

Figure 19

Estimate of 2004-2010 solar power profit pool[1]



[1] Estimate based on informal interviews. See notes on Figures 16 and 18.
Source: CLSA Asia-Pacific Markets

Margin expansion through 2007

3. Stable prices and cost reductions are driving margin expansion

Demand for solar power from end customers in the world's largest markets is far outstripping capacity. The result is that inventories are depleted and waiting time for delivery is, in many cases, four-to-six quarters. Most sales people tell us that they *will not accept new orders for several months* (excluding sales channels they deem to be "strategic") and that the tight supply situation will continue for at least two years. The result of high demand and tight supply is that prices are unlikely to fall anytime soon.

On the cost side, the plant managers and senior executives we interviewed share a general view that *capital and operating costs (on a per watt basis) will continue to decrease at least 5% per year* due to increasing economies of scale, incremental improvements in production, and marginal improvements in cell efficiency (rate of converting inbound sunlight to electricity). Researchers at leading solar institutes believe that one important cost reduction will be the use of thinner wafers, with a decrease from ~300 micrometers to ~150 micrometers taking place in the "midterm" without a significant loss of efficiency.

It is worth emphasizing that this view of cost reduction is based on *incremental* improvements and that *breakthrough* improvements are possible. Similarly, it is worth noting that while government support for solar exists in many markets, a significant "climate change event" (a large ice sheet falls into the north Atlantic and "global warming" is blamed, or major power disruption creates more desire for distributed solar generation) could rapidly expand support and demand for solar.

Figure 20
Representative wafer thickness

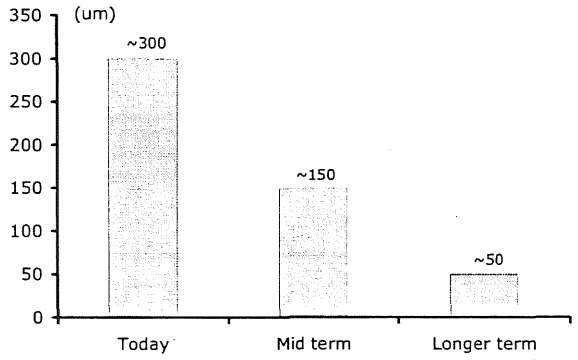
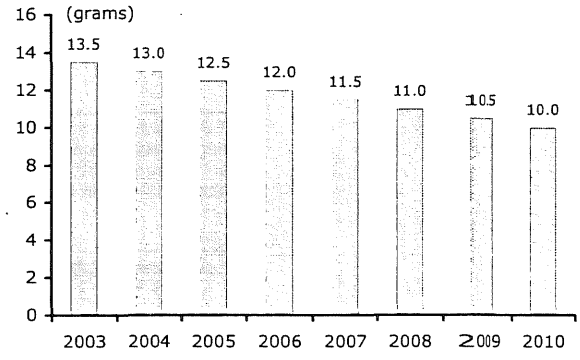


Figure 21
Average silicon/kW



Source: Personal communication, Dr. C Agert, Fraunhofer ISE; Estimate of average silicon/watt is made based on assumption of ~4% efficiency improvement/year through 2010

Silicon is getting more expensive, but increasing cost is being passed to customers

4. Cost increase for silicon passed to customers

The main feedstock for solar cells/modules is high purity silicon, with 12-15 kg of silicon per kW. Silicon is available in solar-grade (slightly less pure) and electronics-grade (slightly more pure). Both grades are acceptable for solar modules, though purer silicon gives better photovoltaic yields. Historically, the solar industry has used scrap, waste, and surplus silicon from the electronics industry, but silicon supplies have become tight in recent months due to fast expansion of the solar sector concurrent with a rebound in electronics demand. In contrast to falling costs in nearly every other area of the solar supply chain, the price of the silicon has increased substantially.

Based on interviews, we estimate that average solar-silicon feedstock prices have increased from ~US$24/kg last year to US$32/kg in 1H04, and are expected to rise further, averaging US$36/kg in 2H04. Similarly, silicon wafer prices increased 10-15% in 1H04 and will likely rise 25% YoY by the end of 2004. We expect that silicon and wafer prices will stay at higher levels for at least three years (the time to bring online a greenfield silicon plant) and could remain high for the rest of the decade. The implication is *quite positive for the profit margins of major silicon manufacturers*. (See further details below in Tokuyama write up, page 59).

While the silicon prices have increased, this is unlikely to have a significant impact on profit margins for downstream solar companies because most senior executives at the larger solar companies say that they are managing based on profit margins instead of simply pursuing volume growth. The result is that the *silicon price increase is being passed on to end customers*. End-customer prices in recent months have risen in Japan and are currently rising in Germany. These end-customer price increases are small (2-3%), but enough to cover the rise in silicon feedstock costs.

Solar's silicon demand is smaller than the electronics industry, but is growing quickly

Figure 22
End use of high purity silicon

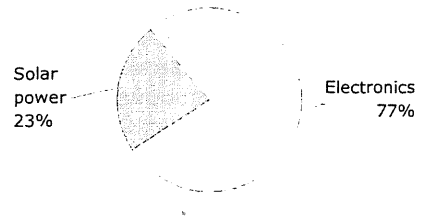
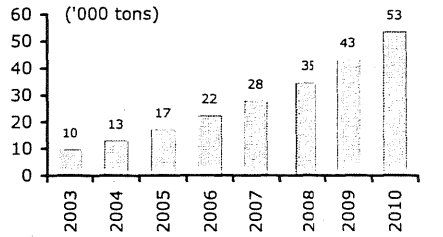


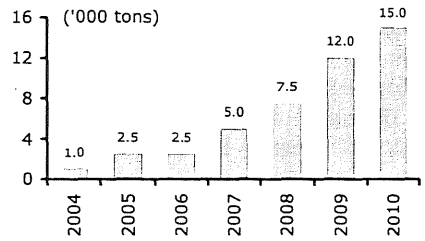
Figure 23
Silicon used for solar power



Source: CLSA Asia-Pacific Markets

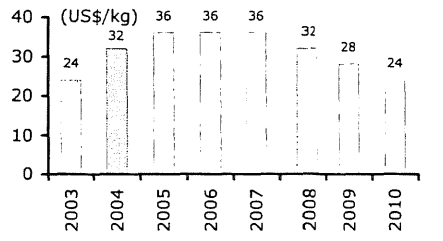
Some predict long-term shortages; we agree until at least 2008

Figure 24
Others: "Silicon Shortage"



Source: Solar Grade Silicon, Inc.

Figure 25
Raw silicon feedstock costs

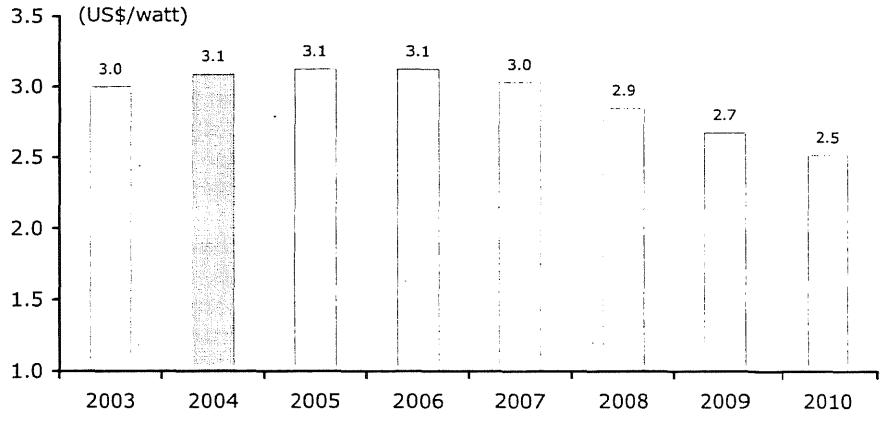


Source: CLSA Asia-Pacific Markets

Prices have started to rise recently and are likely to be up slightly until 2007

Figure 26

Estimate of global average solar module prices



Source: CLSA Asia-Pacific Markets

With conservative capex, we don't expect a major technology leap before 2010

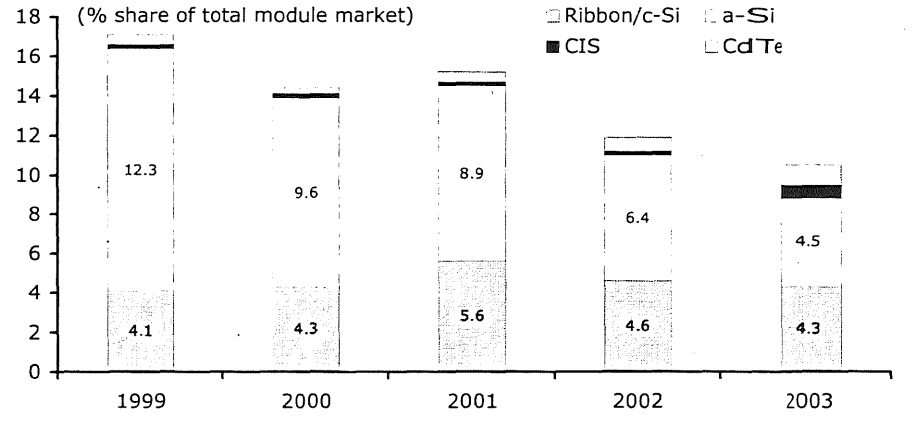
5. Conservative capex decisions make tech revolution unlikely

One surprising theme to come from the interviews was the deeply conservative nature of capex decisions by senior solar executives at the largest solar companies (Sharp, Sanyo, Kyocera, Mitsubishi, BP, Shell). We had expected the heads of these technology-growth companies to be more risk-seeking in their capex decisions, but, almost unanimously, this group refuses to invest significant sums (multiple US$m) until a technology has demonstrated large-scale production capability (RWE Schott is an exception). This is perhaps the result of notable investments by large players (e.g. BP in thin-film technologies) that were unsuccessful. While the largest companies in the sector routinely fund many small tests of new technologies and processes, the vast bulk of actual capex goes for equipment that makes incremental improvements on existing processes and has already been proven in large-scale production. This is because, in the words of one solar CEO, "There are only 15 people in the world who *really* know how to run a solar cell production line greater than 20MW." With a limited talent pool, CEOs are reluctant to fund a major project that could distract time and attention from existing production lines. The result is that the nominees to be the "next" technology for the sector are most likely to be technologies already being used on a fairly large scale. Because of the highly conservative nature of solar capex and the limited pool of talent to manage new (as opposed to incremental) technologies, we believe that we are unlikely to see a major shift in the industry's basic processes until 2010. When the change does come, the most likely nominee is, in our view, ribbon technology because many companies have been burned by investments in thin film technologies over the last 10 years. Ribbon technology is actually a lower-cost variation of normal crystalline production solar cell production but without the need for creating ingots and cutting them into wafers (See additional information on Evergreen Solar, page 41).

Of the commercialized "smaller" technologies, our top nominee to succeed is ribbon

Figure 27

Market share of smaller technologies[1]



[1] For an overview of the various solar power technologies, please see *Solar Electricity (2nd edition)* by Tomas Markvart. Source: CLSA Asia-Pacific Markets and Photon International

Next section: Where to invest

From an attractive industry to attractive investments

In summary, we have come to believe that:

- Solar power is a real industry;
- Solar power it is likely to continue growing quickly through 2010;
- The industry is profitable with expanding margins;
- The next technology shift is at least 5 years away, and that the next major technology shift is 10 or more years in the future; and
- All of this makes for an attractive setting for equity investments.

The preceding pages are a backdrop for equity investors. The following sections lay out a screening process for evaluating equity investment opportunities, reviewing specific investments, and assessing risks to these views.

Minnesota's Solar Energy Future

the green institute

Carl Nelson
Energy Program Director
The Green Institute
cnelson@greeninstitute.org
612-278-7117

MN Senate Jobs, Energy and Community Development Committee

February 23, 2005

1

Green Institute's Involvement

the green institute

- Developed largest solar electric installation in 4-state area
- Developing 20 MW Biomass Cogeneration facility
- Providing assistance to low-income housing developers to incorporate solar thermal
- Working with City of Minneapolis on renewable energy plan
- Developing plan for renewable business incubator

2

Phillips Eco-Enterprise Center's 34 kW system

the green institute

3

Overview

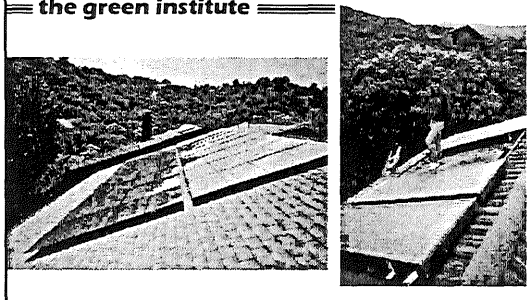
the green institute

- Basic characterization of solar energy
- Rapidly developing technology and market
- MN would benefit from developing a solar strategy

4

Solar electric vs. solar thermal

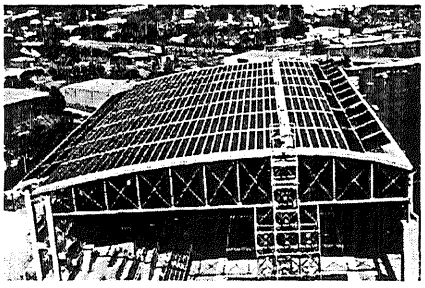
the green institute



5

Solar thermal in Atlanta

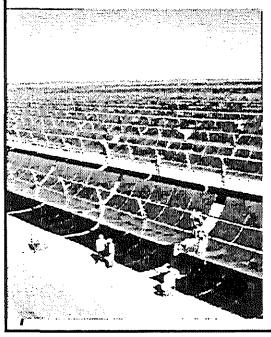
the green institute

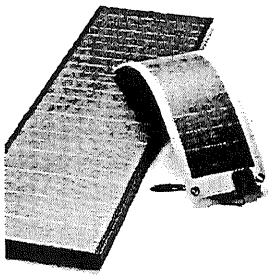


6

Solar electric technology

the green institute

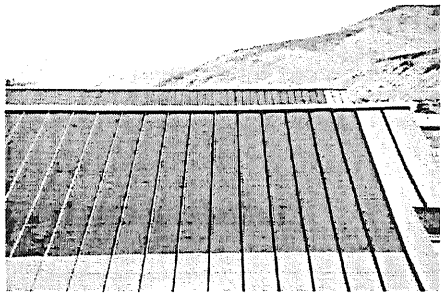




7

Building integrated solar electric

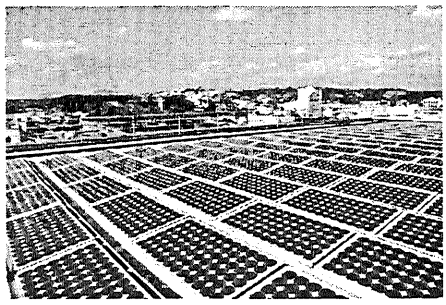
the green institute



8

Commercial solar electric system

the green institute



9

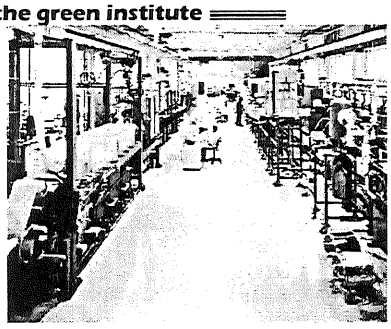
Solar electric manufacturing plant in Arizona

the green institute

10

Solar electric plant, Michigan

the green institute



11

Solar electric plant, Michigan

the green institute

12

MN has plentiful solar resources

the green institute

- Similar to much of Florida, which has a well-developed solar industry
- MN solar resource is greater than that of Germany and Japan, where majority of global installations have occurred

13

Solar offers value as on-site, distributed generation technology

the green institute

- It is a "wireless" technology – no need for transmission lines
- Solar is easily installed in high-density urban areas, where transmission constraints are the greatest
- Since it is an on-site generation source, solar competes in RETAIL, not WHOLESALE power market, where power is worth at least twice as much as "bulk power" from central station power generators

14

Solar coincides with summer peak loads

the green institute

- Air conditioners go on when the sun is shining the brightest
- This coincides with maximum production from a solar electric system
- Thus, solar can make real contributions to reducing peak capacity

15

Solar is zero-emissions, secure energy source

the green institute

- As U.S., MN and local governments develop a greenhouse gas strategy, solar will become increasingly important part of the solution
- Zero mercury emissions
- Solar is a domestic energy source
- Threat of terrorist attack to a rooftop solar installation is virtually zero; can also provide emergency power

16

Solar has seen huge growth over the last 10 years

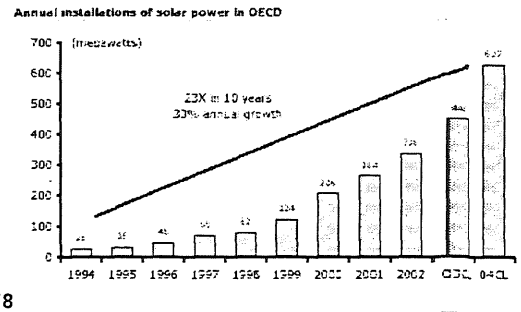
the green institute

- Technology is primarily US, but market is international
- Three largest players are Japan, Germany and U.S.
- Large capital is starting to flow to industry through institutional investors

17

Solar electric has been growing at over 30% per year

the green institute

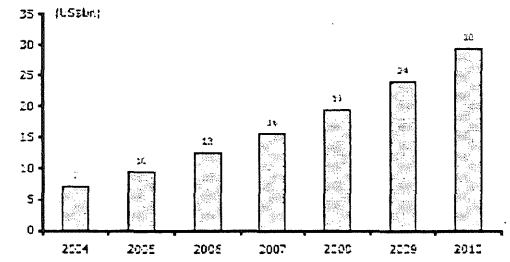


18

Projections are for 30% growth rate to continue for at least 5 yrs

the green institute

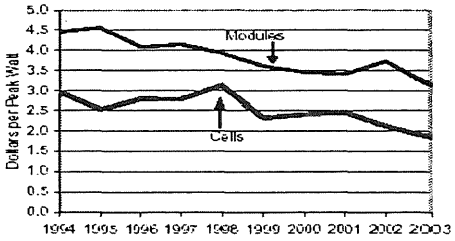
Rough estimate of global solar power market size[1]



19

As a result, prices have dropped for solar panels

the green institute



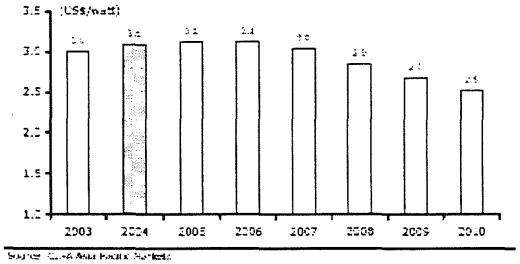
Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Manufacturers Survey."

20

Price decreases are projected to continue at about 4% per year

the green institute

Estimate of global average solar module prices



21

By 2020, U.S. Dept. of Energy estimates residential installations could be 8-10 ¢/kWh

the green institute

Table 4.1.1-2. Targets for Flat-Plate PV Systems in Residential Applications (2-3-kW grid-tied example)

System Element	Units	2003	2007	2020
Design	$/W$_{ac}$	0.25	0.15	0.10
Module Price	$/W$_{dc}$	4.80	2.50	100–1.50
Direct cost/power	$/W$_{dc}$	3.00	1.65	033–0.50
Conversion efficiency	%	14	15	15–25
Direct cost/area	$/m^2	420	250	50–100
Inverter Price	$/W$_{ac}$	1.10	0.50	0.30
DC-AC conversion efficiency	%	94	96	97
Replacement	Years	5	10	20
Other BOS	$/W$_{ac}$	0.85	0.60	0.40
Installation	$/W$_{ac}$	2.50	1.50	0.50
INSTALLED SYSTEM PRICE	$/W$_{ac}$	8.20–9.50*	5.20	230–2.80
System Efficiency	%	11.5	14	16
Lifetime	Years	20	20	30
Degradation	%/Yr	1–2	1–2	1
O&M cost	$/kWh$_{ac}$	0.08	0.02	0.005
LEVELIZED ENERGY COST	$/kWh$_{ac}$	0.25–0.40*	0.22	06–0.10

22

Strategy for solar would maximize benefits to MN

the green institute

- Wind is an area where MN is a national leader in both installation of windpower, and maximization of local benefits
- Solar is currently approximately where wind was 10 years ago
- A strategy now could maximize MN benefits down the road

23

MN has many strategic advantages for the solar economy

the green institute

- University of MN provides research and skilled workforce
  - Initiative on Renewable Energy and the Environment
- MN has complementary industries for solar development
- History of leadership in renewable energy
- Minnesotans embrace new technologies
  - Mpls was rated #1 technology city in the nation by Popular Science

24

Manufacturing sectors in MN projected to benefit from solar growth

the green institute

- Instruments for control and measuring
- Unlaminated plastics
- Electronic equipment components
- Related devices for semiconductors
- Sheet metal work
- Switchgear and switchboard apparatus
- Current-carrying wiring devices
- Storage batteries

25

Extend the sales tax exemption: A modest first step

the green institute

- Wind sales tax exemption was created in perpetuity, but solar sales tax exemption expires in August 2005
- Proposing to extend the sunset, and also have it apply to associated equipment as well as solar thermal systems

26

Conclusions

the green institute

- Solar is valuable addition to the energy portfolio that will increase our future energy security
- Solar technology and markets are booming
- Minnesota could benefit from developing a roadmap for how to capitalize on the future solar economy

27

A Modest Step Forward for Solar in Minnesota
Solar Sales Tax Exemption Proposal

DETAILS OF THE PROPOSAL

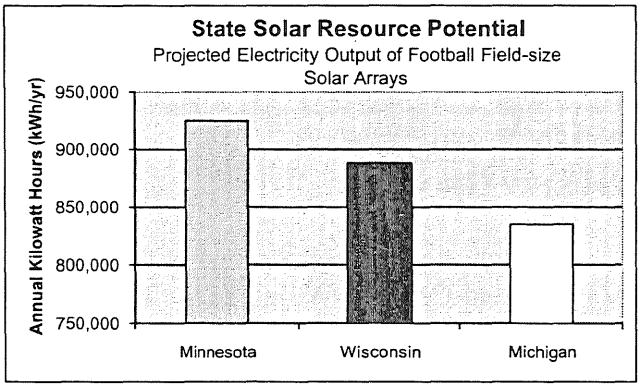
Extend the current sales tax exemption for solar electric panels and expand it to include other solar electric system components (such as invertors, piping, wiring, racks, and batteries) as well as solar thermal system components (such as solar collectors, storage tanks, plumbing pipes, and controls). Estimated cost if proposal had been enacted in 2003/04 biennium: $90,000.

BENEFITS OF PROMOTING A SOLAR ENERGY STRATEGY

- Perfect for Urban Areas (solar energy can be readily integrated into the urban landscape)
- Hedges against Rising Natural Gas Prices
- Ideal for Rural Off-grid Settings (irrigation systems, electric fences)
- Zero Pollution during Operation (no green house gases, no particulates, no air toxics)
- No New Transmission Lines
- Mirrors Current Benefits received by Wind Developers
- Shaves Peak Demand (sun shines during summer day when demand is highest)
- Energy Security (distributed generation using domestic resources)
- Conserves Resources (natural gas, coal, uranium, etc)
- Creates Minnesota Jobs and hence Boosts Minnesota Economy
- Reduces Tax Burden on Interested Customers and Promotes Sustainable Development

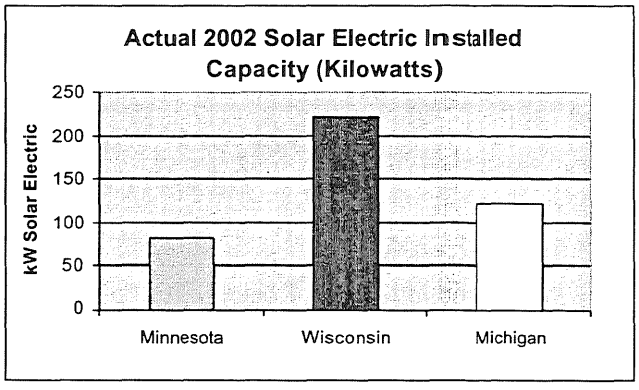
HOW DOES MINNESOTA COMPARE?

Resource Potential:
If you installed a football field-sized solar electric system in each of MN, WI, and MI's sunnier locations, Minnesota's system would have the greatest production:



Source: US Department of Energy, www.eere.energy.gov

Solar Actually Installed:
Though Minnesota's Solar Resource Potential is greater than Wisconsin and Michigan, both WI and MI have installed more solar energy systems than Minnesota:



Source: National Renewable Energy Laboratory, REPi

The Green Institute

Solar Sales Tax Exemption Renewal

Minnesota Renewable Energy Society

BACKGROUND

Minnesota has excellent solar energy resources that are currently extremely under-utilized. Because of our summer days and clear winter skies, most of our state has solar energy potential equal to Houston, Texas or Miami, Florida. Wisconsin, New Jersey, Florida, California are all aggressively promoting solar energy development in their states. By attracting Solargenix, a solar thermal collector manufacturer, the City of Chicago has helped to create approximately 15 manufacturing jobs as well as a number of indirect jobs in the city's equipment, materials, engineering and field service sectors. **The solar industry is currently in a similar position to where the wind industry was 10 years ago in Minnesota – it is critical that we support it at this early stage to ensure we develop this resource to its full potential and stay competitive with other states.** The industry estimates the cost of solar electric to decrease three-fold by 2015, with solar water heating poised to reduce in cost by over 40% by 2009.

MINNESOTA'S EXPERIENCE WITH SOLAR ENERGY SYSTEMS

Minnesota currently has about 160 kW of installed solar power. Solar electricity is being used to provide sufficient electricity to power RV's, cabins, pumping irrigation systems, radio stations, residential homes, and commercial spaces such as the Green Institute in South Minneapolis which has the largest system in the 5-state area. All of Minnesota's highway construction warning lights are powered by solar electricity. Ice cream retailers (such as Izzy's in St. Paul) are installing solar panels to offset their summer refrigeration electricity load; the Wedge Co-op has one of the largest solar hot water heaters in the state.

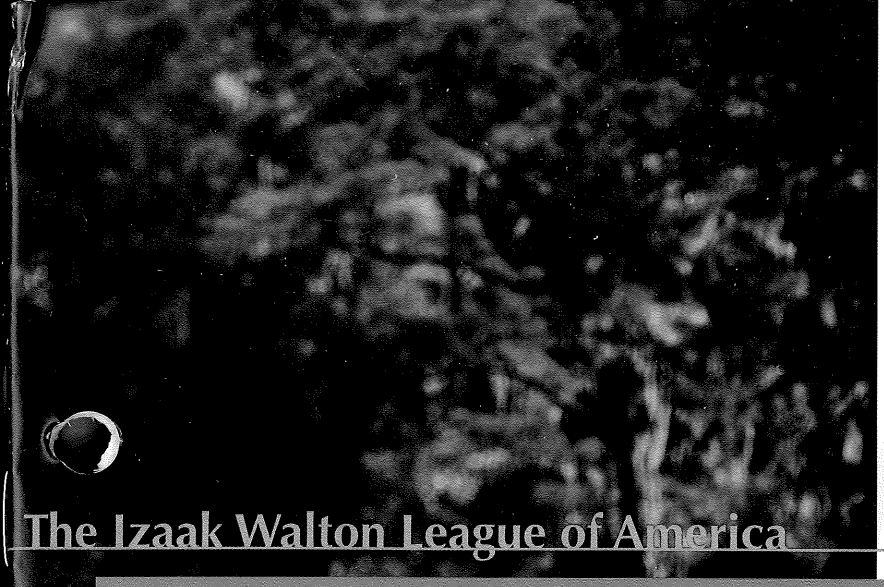
Minnesota could become a Regional Leader in Solar Manufacturing and Installations

Minnesota is one of the top 20 states projected to see benefits from manufacturing, construction, and installation jobs as the solar industry grows --(Source: Renewable Energy Policy Project, January 2005)

MANUFACTURING SECTORS IN MN PROJECTED TO BENEFIT FROM SOLAR INDUSTRY GROWTH

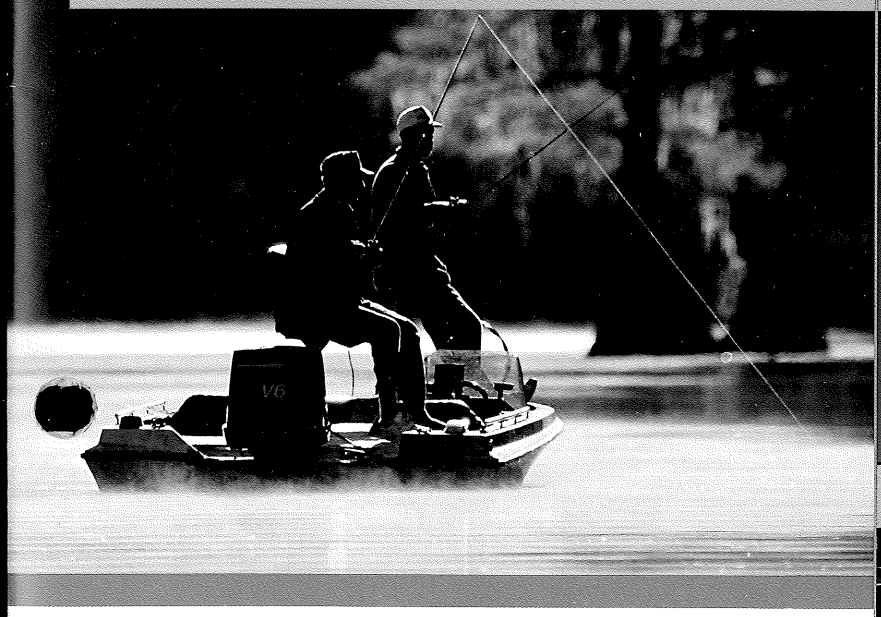
- Sheet Metal Work
- Semiconductors and Related Devices
- Unlaminated Plastics Film and Sheet
- Electronic Equipment Components
- Instrument Measuring
- Switchgear and Switchboard Apparatus
- Current-Carrying Wiring Devices
- Plastics Material and Resin
- Storage Batteries
- Flat Glass

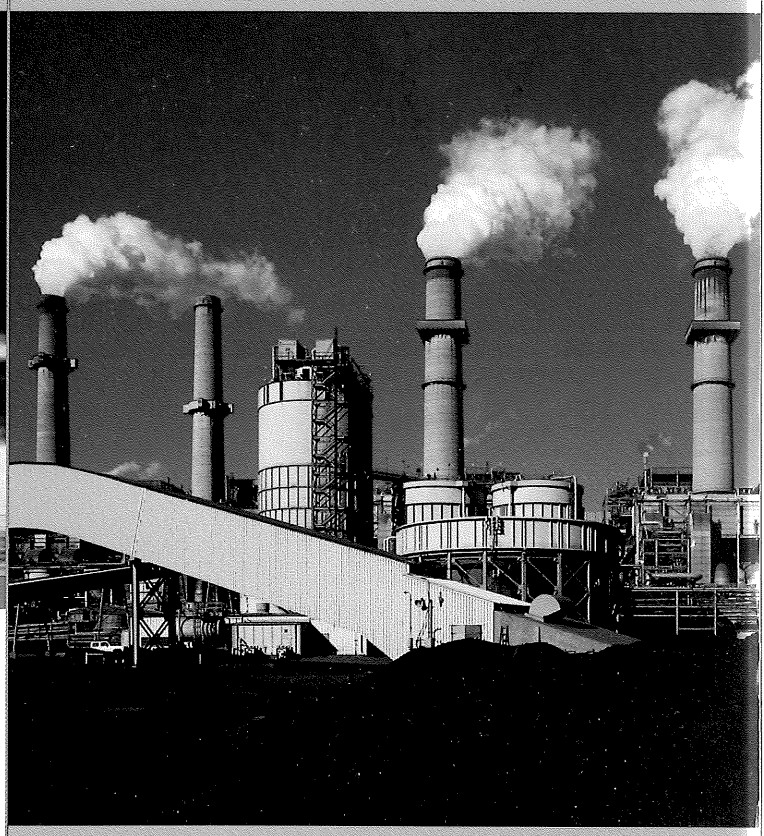
For more information, contact: Carl Nelson, The Green Institute, cnelson@greeninstitute.org (612-278-7117); David Boyce, Minnesota Renewable Energy Society, rkblaw@bitstream.NET, (651-324-1642)



The Izaak Walton League of America

Reducing Mercury Pollution: Workable Solutions for Minnesota's Waters





DEFENDERS OF SOIL, AIR, WOODS, WATERS AND WILDLIFE
THE IZAAK WALTON LEAGUE OF AMERICA

The Izaak Walton League of America

Reducing Mercury Pollution: Workable Solutions for Minnesota's Waters

October 2004
Written by: Sarah Welch and Emily Hansen
Editors: Bill Grant and Jason McGarvey
Design: Sustain

The Izaak Walton League of America gratefully acknowledges the support of the Bush Foundation and the Sustainable Markets Foundation, which made the research and writing of this report possible.

Izaak Walton League of America, Midwest Office
1619 Dayton Avenue, Suite 202
St. Paul, Minnesota 55104

This report is also available at www.iwla.org/cleanair.

Mission Statement: To conserve, maintain, protect, and restore the soil, forest, water, and other natural resources of the United States and other lands; to promote means and opportunities for the education of the public with respect to such resources and their enjoyment and wholesome utilization.

The Izaak Walton League's 40,000 members share our nation's stewardship responsibilities and are dedicated to the common-sense conservation benefiting the nation's wildlife, fisheries, and the outdoors they depend on. The League has chapters in approximately three hundred communities nationwide. Our headquarters is in Gaithersburg, Maryland, and we have a regional office in St. Paul, Minnesota.

Introduction

As the "Land of 10,000 Lakes," Minnesota enjoys a rich tradition of outdoor recreation. Fishing alone contributes $2.8 billion to the state's economy annually.[1] Lakes, rivers, woods, and prairies are a strong part of its identity. The Izaak Walton League of America, whose first national president hailed from Minnesota, has protected this identity for more than eight decades.

Today, mercury contamination from coal-fired power plants and other industrial sources threatens this identity. Fish caught from the state's waters are increasingly contaminated with mercury, a known toxin. Because children are highly susceptible to the adverse effects of mercury, women of child-bearing age, pregnant women, and children must be careful about how much bass, walleye, northern pike, and other sportfish they eat. Fishing is not the safe family activity it used to be.

Reducing mercury contamination has been a priority for Minnesotans since the early 1990s. Realizing that mercury continued to pose serious health risks, the Minnesota Pollution Control Agency (MPCA) formed the Mercury Contamination Reduction Initiative Advisory Council in 1997 to find solutions.

Representatives from Minnesota industries argued that mercury could be reduced voluntarily by 1,000 pounds per year by 2005.[2] Through a consensus process, the Minnesota Mercury Contamination Reduction Initiative agreed to a goal of reducing mercury emissions by 60 percent by 2000 and 70 percent by 2005. The goals were passed in legislation in 1999.

Unfortunately, the goals are not on track to be met. Our analysis demonstrates a reduction of only 5 percent. More than 3,600 pounds of toxic mercury continue to be emitted in Minnesota each year.[3]

New technology is available that could reduce mercury emissions from coal-fired power plants even further. Research is also underway to reduce emissions from the taconite industry. Minnesota must make it economically feasible for businesses to invest in mercury control technologies. The Minnesota law creating the Emissions Reductions Rider is a good example of how incentives can work.

Because some of Minnesota's mercury pollution comes from neighboring states, strong federal regulations are also needed. The U.S. Environmental Protection Agency (EPA) has proposed a rule to control emissions from coal-burning power plants, but the League and the MPCA both agree that the proposal will not be enough.

In this report, the Izaak Walton League argues for the following actions:

- Strengthening the pending federal mercury rule before it is finalized next year;
- Extending the state's Emissions Reduction Rider;
- Providing authority to state agencies to require sector-specific or facility-specific mercury reductions;
- Increasing funding for research and development of taconite mercury controls; and,
- In the absence of a strong federal mercury rule, passing state legislation that requires mercury reductions in Minnesota.

Minnesota's waters, fisheries, and outdoor recreation heritage must be protected.

Why Mercury Is a Problem

Mercury is a naturally occurring element normally found in rocks, soils, and oceans. Since mercury is an element, it never breaks down into a less dangerous form. Instead, it persists in the environment and can cycle for decades between land, air, and water until sediments eventually cover it. Although there are some natural sources of mercury, humans are responsible for nearly two-thirds of the mercury currently circulating in our environment.[4]

Once mercury reaches bodies of water, aquatic bacteria can convert it to methylmercury, a very toxic form that is dangerous to wildlife and humans. The bacteria are eaten by plankton, the plankton are eaten by small fish, and the small fish are eaten by larger fish. The methylmercury concentrates as it moves up the food chain. This process, known as bioaccumulation, explains why bigger and older fish contain the highest levels of mercury and pose the greatest danger to wildlife and humans.

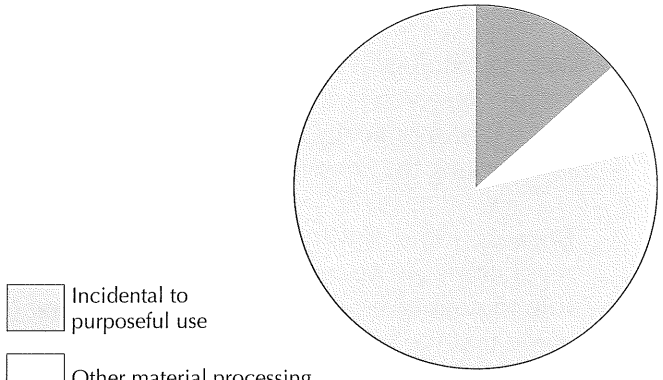
Methylmercury is a potent neurotoxin that can adversely affect development of the human brain and nervous system. Even at low levels, it can delay mental development, cause learning disabilities and deficiencies in language, and impair motor function, attention, and memory.

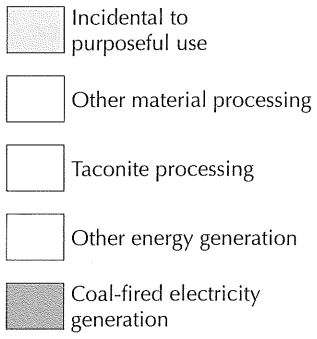
The Minnesota Mercury Inventory

The MPCA worked with industries throughout Minnesota to develop a comprehensive mercury inventory for the state. The inventory includes releases of mercury to the air, water, and land as well as mercury-containing product manufacturing, use, and disposal.[7]

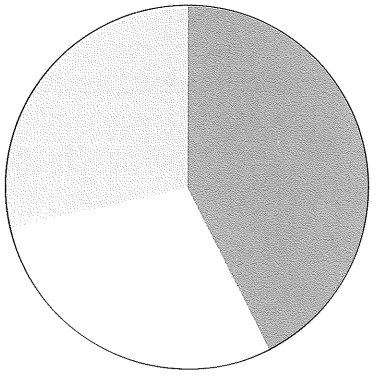
The League believes it is helpful to compare the 1990 and 2000 inventories and to identify the largest emitters. Coal-fired power plants and taconite processing are the single largest mercury-emitting industries in Minnesota. The "incidental to purposeful use" sector (products) as a whole accounted for 79 percent of the inventory in 1990 and only accounted for 29 percent of the inventory in 2000. Clearly, most of the mercury reductions since 1990 have occurred in the product sector, which is comprised of 20 smaller source categories.[8] More reductions should be required of the sectors that have done little to date.

1990 Minnesota Mercury Inventory





2000 Minnesota Mercury Inventory



Source: Minnesota Pollution Control Agency

People are primarily exposed to mercury through fish consumption. Minnesota is one of 21 states to issue a statewide fish consumption advisory because of mercury. The Minnesota Department of Health advises women of childbearing age, pregnant women, and children to limit their intake of fish from *every* lake in Minnesota.[5] Others who consume large quantities of sport fish should also be aware of the consumption advisories.

The concern about fish consumption is easily justified. The U.S. EPA recently reported that one in six women of childbearing age have mercury in their bodies at levels that may adversely affect their unborn child. This could affect up to 630,000 newborns in the United States each year.[6]

Evaluation of the Minnesota Mercury Contamination Reduction Initiative

This section examines the reasons why the Reduction Initiative did not succeed as intended. The voluntary agreements did not meet annual reduction potential of 1,000 pounds per year as recommended by the Advisory Council[9] because:

- The design of the Reduction Initiative was inadequate to achieve the intended results;
- The effort was hampered by a lack of industry-specific goals and uniform reporting standards; and,
- The effort was not focused on direct mercury air emissions, which are the emissions of greatest concern because they are most likely to contaminate fish.

Inadequate Design

The Mercury Contamination Reduction Initiative is a project administered and evaluated by the MPCA. The Mercury Contamination Reduction Initiative's Advisory Council was created in 1997. The Advisory Council was comprised of representatives from industry, government, and nonprofit organizations (see Appendix I for list of participants). Its goal was to advise the MPCA regarding policies designed to reduce mercury contamination and recommend policy-oriented changes.

The U.S. EPA recently reported that one in six women of childbearing age have mercury in their bodies at levels that may adversely affect their unborn child. This could affect up to 630,000 newborns in the United States each year.[6]

Decisions of the Advisory Council were made by consensus. Although stronger provisions for mercury reduction goals and reporting were proposed, the consensus process ultimately rejected them.

By 1999, the Advisory Council recommended quantitative goals to the Legislature. Minnesota Statute §116.915 was passed later that year and established a target for reducing mercury emissions in Minnesota by 60 percent from 1990 levels by 2000 and 70 percent of 1990 levels by 2005. The intent of the 1999 mercury reduction legislation was to ensure that the release of mercury in Minnesota continues to decline. Although legislation was passed, there is no requirement that facilities reduce emissions.

The MPCA faced a great challenge trying to manage a voluntary program. According to the MPCA, the Advisory Council members "insisted that there should be no state mandates. No firm should be forced to (a) develop a voluntary agreement, (b) follow agreement reporting standards or schedules, (c) include in its voluntary agreement any terms specified by the state, (d) meet data collection, maintenance, or reporting requirements, and (e) incur penalties for not developing a voluntary agreement according to state guidelines."[10]

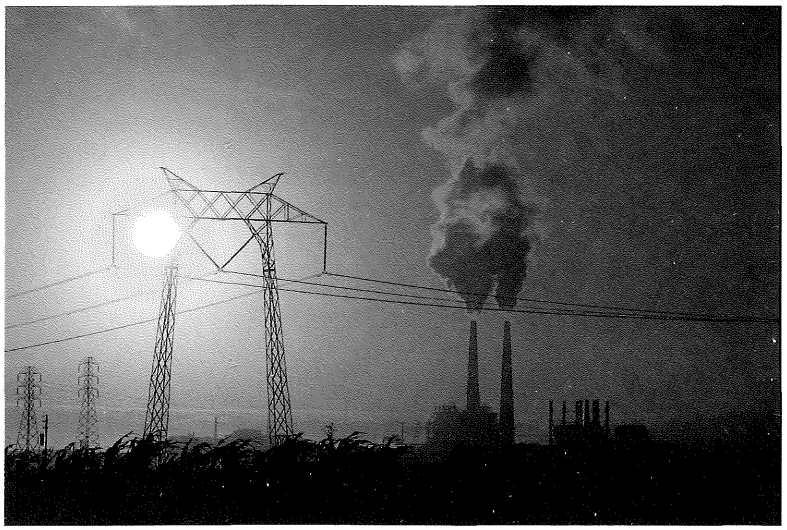
The challenges faced in the Reduction Initiative should be taken into consideration when designing future emissions reduction programs.

No Industry-Specific Goals

It is difficult to plan projects and to quantify results without clearly defined and measurable goals. Either sector- or facility-specific reduction goals are needed to hold the mercury sources accountable for their emissions and to encourage reductions. Electric utilities and taconite processors represent an increasingly large percentage of total Minnesota Mercury Inventory as other sectors take action to reduce emissions. Specific, quantifiable goals are helpful because they provide industries with targets for making reduction decisions.

The MPCA agrees. "Based on program results to date and the results of other voluntary agreement programs in Europe and Canada, specific, measurable targets are a prerequisite to a successful nonregulatory effort."[11]

Furthermore, a lack of uniform reporting standards makes it difficult to quantify any reductions that may have been achieved.



Lack of Focus on Direct Mercury Air Emissions Reductions

Mercury has to enter water in order to contaminate fish. The MPCA has estimated that air emissions are responsible for 98-99 percent of mercury in surface waters; therefore air emissions need to be reduced in order to reduce fish contamination. Much of the effort to reduce mercury to date has focused on reducing mercury in products. According to the MPCA, only an estimated average of 15 percent of mercury contained in products make it to the atmosphere in the first year of disposal.[12] In contrast, 100 percent of mercury air emissions make it to the atmosphere. Pollution control equipment can capture mercury, which is then landfilled. When disposed of properly, mercury is not likely to contribute to fish contamination.

The industries submitting voluntary agreements did take some action on the mercury issue. Some conducted studies of their facilities to understand where mercury was used or emitted. Many replaced equipment and instruments that contained mercury with products that did not. Some participants made significant contributions toward removing mercury products from their communities – through mercury thermometer collections, for example. These efforts

are commendable. However, there is no reason to believe that mercury existing in these products would ever have been improperly released into the environment. Potential reductions from collection programs cannot be compared to the benefits of reducing direct mercury air emissions on a daily basis.

Table 1: Direct Mercury Air Emissions Reductions[13]

	Direct Air Emissions Reduced (pounds per year)
Xcel Energy	up to 35
Western Lake Superior Sanitary District	~10
Minnesota Power	up to 57
North Star Steel	2
Metropolitan Council Environmental Services	78
Pounds reduced	up to 182

** Note that the Toxic Release Inventory (Appendix II) shows electric utility mercury air emissions increasing in the 2000-2002 period.*

Table 1 is the League's analysis of the mercury air emissions that were reduced as a result of the Reduction Initiative, based on the progress reports submitted by the participating industries. These are self-reported emissions reductions by industry and have not been independently verified.

The two largest sources of direct mercury air emissions in Minnesota are the electric utility industry and the taconite industry. The taconite industry accounts for 21 percent and the electric utility industry accounts for 42 percent of the 2000 Minnesota Mercury Inventory.

Taconite Industry

Although members of the taconite industry submitted voluntary agreements, no mercury emissions reductions have likely resulted except in the case of facility closures. Facility closures are not the outcome sought by the League.

Electric Utility Industry

Of the approximately 1,545 pounds of mercury air emissions emitted from coal-burning power plants annually, just over 6 percent – approximately 92 pounds – has been eliminated through the Reduction Initiative. These reductions have come from two actions.

Minnesota Power committed to include coal mercury content as a consideration when making coal-purchasing decisions, since coals can have varying mercury content. Beginning in 2000, Minnesota Power increased its amount of lower mercury coal purchases and achieved a reduction of approximately 57 pounds from 1990 levels. It is unclear whether or not these reductions are ongoing.

Xcel Energy completed the conversion of its Black Dog plant from coal to natural gas, which resulted in a reduction of up to 35 pounds per year beginning in mid-2002.

Metropolitan Council Environmental Services (MCES) is expecting to reduce direct mercury air emissions by 78 pounds per year beginning this year. MCES is installing a new air pollution control system for their incinerators. The Western Lake Superior Sanitary District discontinued their sludge incineration process and decreased their air emissions 100 percent. North Star Steel reported in 2001 that they undertook roof repairs to reduce fugitive mercury emissions by two pounds per year.

The League is most concerned about direct mercury air emissions from smokestacks because these are the type of mercury emissions that are most likely to result in fish contamination. Our analysis demonstrates that only about five percent of these most harmful emissions were reduced through the Reduction Initiative.

Approach Is Not Viable for the Future

According to the MPCA, more than 3,600 pounds of toxic mercury continue to be emitted in Minnesota each year.[14] The single-largest source of mercury emissions in Minnesota is Xcel Energy's Sherburne County (Sherco) power plant. Emitting 886 pounds of mercury air emissions in 2000, Sherco not only tops the list of mercury emitters, but also contributes well over three times as much mercury as the second largest polluter in the state, which is Minnesota Power's Clay Boswell Energy Center.

Sherco accounts for approximately 25 percent of the total mercury emissions in Minnesota. The Sherco plant is very large, with a power production capability of 2,254 megawatts. Every day, 30,000 tons of coal – equivalent to three 100-car trainloads of coal – are burned in Sherco's three boilers.[15] Although significant efforts have been made to control emissions of sulfur oxides, nitrogen oxides, and particulate matter, further controls are needed to reduce the largest source of mercury pollution in the state.

Sherco is the largest, but it is not the only large source in Minnesota. The extent of the mercury pollution problem is best understood by looking at the largest emitters in the state.

The taconite industry is currently enjoying a resurgence. As more facilities become operational, mercury air emissions from this sector will increase. Technologically and economically feasible

Table 2: Top 10 Mercury Emitters in Minnesota

Facility	MPCA 2000 Minnesota Mercury Inventory[16]
Xcel Energy Sherburne County Generating Plant, Becker	886 lbs
Boswell Energy Center, Cohasset	263 lbs
Hibbing Taconite Company, Mesabi Range	225 lbs
North Star Steel, St. Paul	176 lbs
U.S. Steel (Minntac), Mesabi Range	171 lbs
National Steel Pellet Company, Mesabi Range	121 lbs
EVTAC Mining, Mesabi Range	106 lbs
Xcel Energy Riverside Generating Plant, Minneapolis*	98 lbs
LTV Mining, Mesabi Range**	83 lbs
Xcel Energy King Generating Plant, Bayport*	67 lbs

**Mercury emissions will be reduced 20% at King and 100% at Riverside through Xcel Energy's Metro Emissions Reduction Program.*
*** This facility is no longer operating.*

emission control equipment has not been developed to control mercury emissions from taconite processing. The industry has participated in limited research to develop such mercury emissions controls. Minnesota should support further research in this area.

Demand for energy is also expected to increase in the future. As demand rises, it is likely that coal combustion will increase. Either more coal-burning power plants will be built, or existing coal plants will increase their capacity. Minnesota mercury levels from this sector will rise in the future unless control technologies are employed. Clearly, a great deal of work remains to control the mercury pollution problem and make Minnesota's fish safe to consume again.

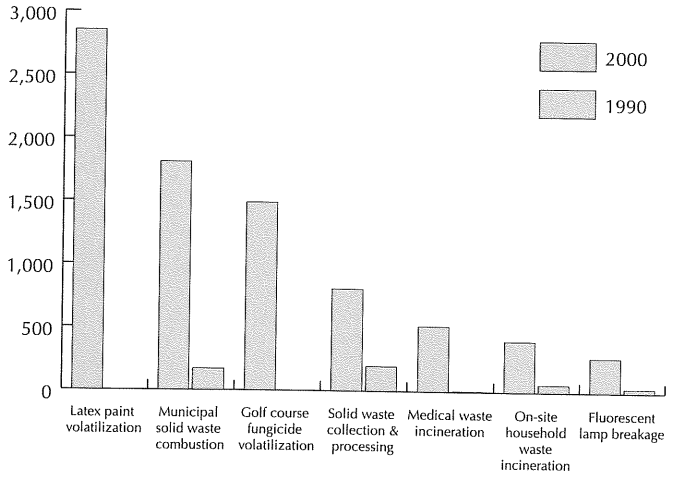
Conclusions from the League's Analysis

Since the voluntary agreements were first submitted in 2000, they have led to a reduction of direct mercury air emissions of less than five percent.[17] It is clear that the voluntary agreements did not result in significant direct mercury air emissions reductions.

Future reductions of mercury air emissions will be necessary. The Izaak Walton League recommends that Minnesota policy-makers take the lessons learned from the Reduction Initiative into consideration. In future mercury emission reduction efforts, policy-makers should focus on reductions of direct air emissions, which are the emissions of greatest concern with regard to fish consumption. Moreover, future policy should include industry-specific goals and should require firm and uniform reporting standards.

Majority of Mercury Reductions Occurred Before the MCRI

From 1990 to 2000, air emissions of mercury in Minnesota declined by 68 percent, exceeding the 2000 goal set by the 1999 legislation.[18] While it appears that the Reduction Initiative has been very successful in surpassing their goal, the real story is more complicated. Because of a shift in the 1990 baseline, the percent decline in mercury emissions between 1990 and 2000 is much greater than originally estimated. In addition, nearly all the reductions that have occurred are due to state and federal actions in the 1990s (for state actions, see Appendix III). Most of the reductions relate to the intentional use of mercury or management of mercury-containing products.



Federal bans in the early 1990s on mercury used as a fungicide in paint and used in snow mold control resulted in a 38 percent mercury reduction. A combination of Minnesota's 1995 waste combustor standards for municipal and medical waste incinerators and previous voluntary efforts in that sector led to another 19 percent reduction.[19]

Additional Minnesota legislation passed in the early 1990s banned the use of mercury in certain products, prohibited the disposal of mercury in solid waste, and required the management and recycling of lamps and other items. These actions led to more reductions in mercury releases to the environment.

These reductions that occurred before the Reduction Initiative was implemented and that occurred as a result of federal and state regulation are good, but should not be attributed to the success of the MCRI. In fact, using the revised baseline, it is likely that Reduction Initiative met its own goals prior to the legislation even taking effect.

Federal Action to Reduce Mercury

Although Minnesota sources produce over 3,600 pounds of mercury per year, not all of that mercury is deposited directly into Minnesota waters. Air pollution does not respect political boundaries such as state lines. MPCA estimates that only about 10 percent of the mercury deposition to Minnesota waters comes from Minnesota sources. The vast majority of our mercury emissions are transported out of state to contaminate the waters in neighboring states.

Some interests may argue that because so much mercury in Minnesota's water comes from out of the state, strict controls on sources within Minnesota are unwarranted. The Izaak Walton League disagrees. Minnesota needs to lead the effort to show others, both regionally and globally, that effective mercury control is feasible. Given the complex nature of the mercury contamination problem, Minnesota needs to advocate for a strong federal solution.

In December 2000, the U.S. EPA found that it is "appropriate and necessary" to regulate coal- and oil-fired electric utilities using maximum achievable control technologies (MACT) as required by the Clean Air Act. In January 2004, EPA proposed three alternatives for controlling air toxics, including mercury, emitted from power plants:

1) Require power plants to meet emissions limits consistent with MACT;
2) Create a market-based cap-and-trade program; or,
3) Create a cap-and-trade program that is federally run.

EPA asserts it will finalize a rule to control air toxics, including mercury, from power plants by March 15, 2005.

EPA is charged with regulating hazardous air pollutant (HAP) emissions from all industries, including the utility industry. These HAPs include many compounds that cause multiple and extreme adverse health effects in humans. Among them are mercury compounds, known human neurotoxins listed since 1971 by EPA and since 1990 by Congress as a HAP requiring maximum control. But EPA's proposal does not satisfy this requirement; indeed, its third alternative treats mercury as though it were a conventional air pollutant.

Minnesota needs to lead the effort to show others, both regionally and globally, that effective mercury control is feasible.

The League is troubled that EPA's proposals are all much weaker than what the Clean Air Act requires and what is known already to be achievable and cost-effective in this industry. Most notably, the proposal is weaker than reduction levels the EPA itself has previously suggested.

Assuming 90 percent of the mercury deposited into Minnesota comes from sources outside of the state, the League also recommends that Minnesota officials argue much more vocally and publicly that the proposed rule pending before EPA needs to be strengthened.

The MPCA took the first step, commenting to EPA in June 2004 that the proposed rule, "will not likely result in significant mercury reductions from power plants in and upwind of Minnesota."[20]

The MPCA argues that Minnesota needs a stronger federal rule to attain mercury water quality standards that cannot be achieved by reduction of state emissions alone. It also recommends

Metro Area Reductions Project

Xcel Energy will reduce emissions from three coal-burning power plants in the Twin Cities metropolitan area through its Metro Emissions Reduction Project (MERP). The Emissions Reduction Rider statute, passed in 2001, afforded Xcel Energy this opportunity. Xcel Energy and the Izaak Walton League of America signed an agreement in which Xcel committed to proposing an emissions reduction project in 2001.

"The opportunities offered by the Emissions Reduction Statute spurred us to propose initiatives that balance the interests of the environment, our customers, and future energy supply needs in the region."

- Judy M Poferl, director of Xcel Energy's Regulatory Administration, in a letter to the Minnesota Public Utilities Commission, May 3, 2002.

Xcel filed a petition for approval with the MPUC in May 2002 and it was approved in December 2003. The High Bridge power plant in St. Paul and the Riverside power plant in Minneapolis will be converted to natural gas. Xcel expects a 100 percent reduction in mercury emissions from both the Riverside and High Bridge plants. State-of-the-art emissions control equipment will be installed at the Allen S. King power plant in Oak Park Heights. Xcel Energy expects a 20 percent reduction in mercury emissions at the King plant. All three projects are scheduled to be completed by 2009 and will result in approximately 170 pounds of mercury reduced per year.

that the agency set more aggressive timelines by which emissions reductions must be achieved. Taking more aggressive steps to control mercury emissions is likely to result in rapid technological development that would not only benefit us by reducing emissions in the United States, but also by assisting to reduce emissions in the global community.

The League recommends that Minnesota policy-makers ask EPA to:

- Finalize a MACT standard that meets the requirements of the Clean Air Act and, through that standard, require a 90 percent reduction of electric utility mercury emissions by 2008.
- Reject the alternative performance standard approaches and the associated mercury trading proposals. These alternatives would cause additional mercury-related health risks through the promotion of pollution trading and would allow unacceptable amounts of mercury pollution to continue.

Other State Opportunities

Recognizing that the electric utilities have had little incentive to voluntarily reduce their emissions, the Minnesota Legislature passed Minnesota Statute §216B.1692, the "Emissions Reduction Rider," in 2001. This legislation creates an incentive for utilities to reduce emissions by allowing for the recovery of costs of qualifying emissions reductions projects without the need for a general rate case. This eliminates the regulatory lag (the time between expenditures for emission control equipment and recovery of those costs from customers in rates) and makes it possible for utilities to take on large reduction projects. For approval of an emissions reduction rider, a utility must submit a plan, which both the MPCA and Minnesota Public Utilities Commission (MPUC) must review for environmental and economic appropriateness. All investor-owned utilities

Photo: Chicago Wilderness

in Minnesota are currently eligible to apply for the emission reduction rider, which expires on June 30, 2006.

The Izaak Walton League supports extending and further utilizing the Emissions Reduction Rider to encourage additional emission reduction projects. Similar incentives should also be made available to municipal utilities and electric cooperatives.

Technology to Get the Job Done

Some contend that the technology to reduce mercury from coal-fired electric utilities is not available at this time. In fact, the opposite is true. There are several approaches to controlling mercury emissions available today, some even employed by Minnesota utilities. Options include:

- Coal cleaning as a pre-combustion alternative;
- Installing conventional controls;
- Optimizing the mercury capture of existing control devices for other pollutants;
- Adding mercury-specific controls; and,
- Multipollutant approaches (e.g. strategies to simultaneously reduce mercury, nitrogen oxides, sulfur oxides, and particulate matter pollution).

Other State Legislation

Massachusetts

Although the state's four coal-fired power plants already capture an average of 67 percent of the mercury in the coal burned at their facilities, the Massachusetts state government adopted new regulations in 2004 to further reduce the amount of mercury emitted. By January 1, 2008, each power plant must capture at least 85 percent of the mercury. The percentage of mercury that must be captured increases to 95 percent by October 1, 2012.[25] This will lead to annual mercury emission reductions of about 155 pounds.[26] The Massachusetts Department of Environmental Quality estimates that if facilities pass the capital and operating costs of mercury controls on to consumers, a typical household would pay an additional $0.09 to $0.81 per year.[27]

Wisconsin

This year Wisconsin has done what no other state in the Midwest has done – passed a statute requiring cuts in mercury pollution from coal-burning power plants. Other states, such as Connecticut, Massachusetts, and New Hampshire, have also recently passed mercury control legislation. But while Eastern states generally burn bituminous coal, Wisconsin and many Midwestern states (including Minnesota) burn mostly subbituminous coal. It is more difficult to remove mercury from subbituminous coal than bituminous. But Wisconsin believes subbituminous coal can be burned cleaner, and needs to be burned cleaner, to protect Wisconsin's waters.

Wisconsin's rule requires major utilities to reduce their baseline mercury emissions 40 percent by 2010, and by 75 percent by 2015.[28] Although some feel that the rule is not strong enough, it will help drive the development of mercury control technology for subbituminous coal plants.

When the federal mercury rule is finalized, Wisconsin's mercury legislation requires that the state rule cannot be stricter than the federal standard. Although the federal rule may be held up in litigation, Wisconsin's power plants will be reducing their mercury emissions and setting an example for other states.

Mercury Controls On New Power Plants

Xcel Energy has recently proposed to add a 750-megawatt boiler that will burn subbituminous coal to its existing Comanche plant near Pueblo, Colorado. Construction plans include numerous environmental controls, including technology to reduce mercury emissions:

"Public Service believes that it can comply [with mercury limits] by using the proposed baghouse in combination with activated carbon injection technology or other non-carbon based sorbent technologies. The use of other commercially available mercury sorbent technologies is also being considered for Comanche 3."

- Olon Plunk, Direct Testimony, In the Matter of the Application of Public Service Company of Colorado for a Certificate of Public Convenience and Necessity for the Comanche Unit 3 Generating Facility
April 3, 2004

MidAmerican Energy received a permit from the Iowa Department of Natural Resources (IDNR) in 2003 to construct a new 190-megawatt generating unit in Council Bluffs, Iowa, which will also burn subbituminous coal. The unit will likely begin operation in 2008. The IDNR has determined that an activated carbon injection system can achieve at least 83 percent mercury control.

These new construction plans demonstrate that utilities believe effective mercury control is achievable.

Regulation can drive technological advancements. According to the Northeast States for Coordinated Air Use Management, control technology innovation has occurred only after environmental regulations have been put into place. In addition, using the history of nitrogen oxides and sulfur oxides regulation as examples, estimates of compliance costs prior to regulation are often well above actual compliance costs. Further, looking at the success of waste combustors, it is clear that dramatic mercury reductions can be achieved through regulatory requirements.[21]

Technologies designed to specifically capture mercury, or that offer multipollutant benefits, are in various stages of development ranging from bench-scale testing to commercially available. We believe that regulation is likely to further spur the development of these technologies and help create new markets for control technology vendors.

Several states have already pursued and passed mercury reduction legislation for electric utilities, including Wisconsin, Connecticut, Massachusetts, New Hampshire, and New Jersey. Their regulations are much stricter than EPA's proposed rule. Unlike power plants in Eastern states, which burn bituminous coal, Minnesota power plants overwhelmingly burn subbituminous coal. It can be easier to remove mercury from bituminous coal compared to subbituminous coal. However, much of the legislation from other states relies on the development and availability of technology to reduce mercury.

A survey of some mercury capture technologies and their capture efficiency is presented in Table 3.

Table 3. Mercury-Specific or Multipollutant Control Technologies[22 23 24]

Mercury Control Approach	Percent Mercury Capture	Comments
Conventional coal cleaning	23%	Average removal for eastern bituminous coals.
Optimization of existing controls	Variable	Incremental increase in performance.
Installation of conventional controls	29%	National reduction achievable through implementation of proposed Clean Air Interstate Rule.
Activated carbon injection with an electrostatic precipitator for particulate matter control	60%	Addition of a small fabric filter would increase the capture efficiency to 90%. Saving in sorbent costs would pay back the cost of the fabric filter in three to four years.
Activated carbon injection with existing fabric filter for particulate matter control	90%	For subbituminous and lignite coals, an activated carbon that is treated with iodide, sulfur, or bromine would probably be needed to achieve this high level of reduction.
COHPAC-TOXECON™	90%	This configuration is a small fabric filter in combination with activated carbon injection. High capture efficiency for all coal types.
Enhanced wet scrubbing	50% – 80%	Control efficiencies vary with scrubber chemistry. Avoids excess carbon in the fly ash.
K-Fuel®	70%	Advanced coal cleaning techniques for subbituminous coals.
Powerspan – ECO®	80% – 90%	Multipollutant control. Also removes 98% of sulfur dioxide, 90% of nitrogen oxides, and 99.5% of fine particulate matter ($PM_{2.5}$).
Advanced Hybrid Filter™	>90%	Used in conjunction with activated carbon injection.
Airborne Process	Up to 75%	Multipollutant control. Also removes >95% of sulfur dioxide, 60 to 79% of nitrogen oxides.
LoTox™ Process	> 90%	Multipollutant control. Also removes >90% of nitrogen oxides.
MerCAP™ (Mercury Control via Adsorption Process)	> 80%	This places fixed structures into a flue gas stream to absorb mercury.

Recommendations and Conclusions

The League is concerned because mercury contamination of fish has an adverse effect on our health, our economy, and our fishing traditions in Minnesota. Mercury poses serious health risks to the developing fetus and to young children. Mercury contamination threatens the resource on which sport fishing depends and has real economic consequences for League members and the whole of Minnesota.

The League believes that market mechanisms and voluntary efforts can result in successful outcomes. However, the disappointing results of the Reduction Initiative demonstrate that significant results do not occur without clear goals and regulatory requirements. We applaud all mercury reductions. The League remains concerned, however, that the Reduction Initiative did not result in significant reductions of direct mercury air emissions. After reviewing the available data, we must conclude that the Reduction Initiative did not succeed.

The League stands ready to work with responsible businesses and government agencies to find more successful means of addressing our mercury pollution problem.

Minnesota has been a leader for decades in air pollution reduction, beginning with our efforts to address acid rain in the 1970s. Minnesota needs to, and can, show other states how to reduce mercury emissions while maintaining a strong business economy.

The technology to solve the mercury problem can be further developed with the proper incentives and regulations at the state and federal levels. New markets will open as a result of employing technologies to curb mercury emissions.

The League stands ready to work with responsible businesses and government agencies to find more successful means of addressing our mercury pollution problem.

The Izaak Walton League recommends the following actions:

- Strengthen the pending federal mercury rule before it is finalized next year;
- Extend the state's Emissions Reduction Rider;
- Provide authority to state agencies to require sector-specific or facility-specific mercury reductions;
- Increase funding for research and development of taconite mercury controls; and,
- In the absence of a strong federal mercury rule, pass state legislation that requires mercury reductions in Minnesota.

Appendix I: Mercury Contamination Reduction Initiative's Advisory Council

Member	Main Alternate	Representing
Peter Bachman	Bob Eleff	Minnesota Center for Environmental Advocacy
Alexis Cain	Frank Anscombe	US EPA Region 5
Richard Diercks	Susan Lightfoot	Minnesota Dental Association
John Dwyer	Clifford Porter	Lignite Energy Council
David Festa	Stacey Davis	Center for Clean Air Policy
Rebecca Flood	Leo Hermes	Metropolitan Council
Dr. Daniel Foley, Chair	David Thornton	Minnesota Pollution Control Agency
Brian Golob	Jan Nisiewicz	Recylclights
Pam Graika	Lee Eberley	Northern States Power
Bill Grant	Amy Fredregill	Izaak Walton League of America
J. Drake Hamilton	Michael Noble	Minnesotans for an Energy-Efficient Economy
Ann Glumac Dave Skolasinski	Stephani Campbell Scott Hautala	Minnesota Iron Mining Association (Campbell is with MnTAC)
Diane Jensen	Marie Zellar	Clean Water Action/The Minnesota Project
Dave Jeronimus	Tim Hagley	Minnesota Power
Kathy Svanda	Pat Bloomgren	Minnesota Department of Health
Will Kaul	Karen Utt	Cooperative Power
Steve Keefe		Honeywell, Inc
Rich Korman Scott Grosscup		Minnesota Hospital and Healthcare Partnership
Gail Lewellan	Jack Skrypek	Minnesota Department of Natural Resources
Carl Michaud	Dave Wierens	Association of Minnesota Counties
Sherry Munyon Rolf Hanson		Minnesota Chamber of Commerce
Trudy Richter	Rob Dunnette	Minnesota Resource Recovery Association
Michael Robertson		Minnesota Forest Industries
Larry Schwarzkopf	Fred Vande Vetter	Fond du Lac Indian Reservation
Tim Tuominen		Western Lake Superior Sanitary District
Rosemary Wilson	John Knapp Molly Sigel	Center for Energy and Economic Development

Appendix II: Toxic Release Inventory: Summary of Minnesota Electric Utilities[29]

Facility Name	Mercury Releases (lbs)		
	2000	2001	2002
Northeast Power Station, Austin Public Utilities	7	8	7
Hibbing PUC	6	6	6
Boswell Energy Center, Minnesota Power	263	286	297
Laskin Energy Center, Minnesota Power	20	19	19
Taconite Harbor Energy Center, Minnesota Power	NA	NA	46
Minnesota Power subtotal:	**283**	**305**	**362**
Hoot Lake, Otter Tail Power Company	37	31	32
Silver Lake, Rochester Public Utilities	5	2	NA
Allen S. King, Xcel Energy	68	64	70
Black Dog, Xcel Energy	50	36	48
High Bridge, Xcel Energy	66	71	67
Sherco, Xcel Energy	884	843	876
Riverside, Xcel Energy	98	92	104
Xcel Energy subtotal:	**1,166**	**1,106**	**1,165**
Electric Utility Totals:	**1,504**	**1,458**	**1,572**

Appendix III: Summary of Mercury Reduction Strategies Employed in Minnesota Since 1990.

Voluntary Programs	
Household/Small Business Hazardous Waste Collection 1990s-present	Many county-run programs that accept mercury-containing items from homeowners and businesses.
Health Care Outreach 1994-present	Education to encourage management and reduction of mercury-containing equipment.
Dental Office Outreach Late 1990s-present	Municipal wastewater-treatment plants and the Minnesota Dental Association conducted outreach, established best management practices and set goals for 100% participation.
Voluntary Reduction Agreements 1999/2000 –2005	Large emitters enter into voluntary agreements to reduce emissions.
Mercury Switches in Automobiles 2000, 2004	Major MN steel recycler offers bounty of $40/lb of bare switches offered (2000). Program operated by MN Waste Wise and funded by auto manufacturers provides free collection, transportation and recycling for auto switch assemblies (2004).
Mercury-Free Zone Program 2001-present	Schools pledge to become and stay mercury free and receive an assessment, curriculum, video and often educational visit by the MPCA's mercury educator, Carol Hubbard, and Clancy, its mercury-detecting dog.
Regulatory Programs	
Waste Combustor Standards 1993-1995	Sets air emission limits on mercury and requires mercury-reduction plans for municipal and medical waste incinerators.
Water Discharge Standards 2001	Wastewater dischargers are required to monitor for mercury using EPA Method 1631; mercury effluent limits are set in some cases.
State Laws	
Commercial-Use Battery Manufacturer Responsibility 1990	Requires manufacturers to take back non-household use batteries that are hazardous when discarded, including mercuric oxide and silver oxide batteries.
Battery Mercury Reduction 1990, amended in 1991-1993	Law bans mercuric oxide batteries and the addition of mercury to alkaline batteries. Establishes a 25-mg limit in button batteries.
Toxics in Packaging 1991	Prohibits the intentional introduction of mercury (and 3 other metals) into packaging.

Toxics in Products/ Listed Metals in Specified Products 1991 with later amendments	Prohibits the sale of inks, pigments, paints, dyes and fungicides containing mercury (and three other metals) unless exempted. No mercury exemptions were granted.
Thermostat Take-back 1992-present	Requires thermostat manufacturers to provide education and incentives for thermostat recovery and recycling. Through a reverse distribution system involving contractors and wholesalers, manufacturers take back out-of-service units.
Major Appliance Components 1992	Requires removal and recycling of mercury-containing components in major appliances, including components removed by service and repair companies.
Mercury in Construction/ Demolition 1992	Prohibits disposal, implying removal before demolition. Education and enforcement conducted.
Mercury Product Labeling Enforcement 1992	Requires labeling of most mercury-containing products. MPCA enforcement actions related to labeling resulted in withdrawal of several products from the Minnesota market and in some cases spurred manufacturers to completely discontinue their manufacture and sale.
Mercury-containing Product Sales Bans 1992, 1994, 2001	Toys, games (1992), apparel (1994) and thermometers (2001) that contain mercury may not be sold in Minnesota.
Fluorescent Lamp, Other Product Disposal Ban 1993/1994	Requires businesses and households to recycle fluorescent lamps, stimulating development of recycling infrastructure.
Auto Switch Removal 1996	Requires "good faith effort" to remove mercury switches prior to crushing.
Dairy Manometer Ban and Buy-back 1997	Bans the sale, installation, repair, and use (after 12/31/2000) of mercury-containing manometers, establishes $100 incentive for turning in old gauge.
Relay Manufacturer Responsibility 1997	Requires manufacturers of mercury displacement relays to provide education and incentives, and cover costs of managing out-of-service units.
Mercury Reduction Law 1999	Requires the State of Minnesota to pursue Advisory Council-recommended strategies, establishes a goal of 70% reduction in emissions by 2005 based on 1990 levels. Final report due in 2005.

Endnotes

[1] American Sportfishing Association, 2001. "Sportfishing in America: Values of Our Traditional Pastime," page 9. Based on a ten percent update for 2001 inflation.

[2] Minnesota Pollution Control Agency, 1999. Report on the Mercury Contamination Reduction Initiative: Advisory Council's Results and Recommendations.

[3] Minnesota Pollution Control Agency, 2004. Estimated Mercury Emissions in Minnesota for 1990, 1995 and 2000: March 2004 Update. http://www.pca.state.mn.us/publications/reports/mercury-emissionsreport-0304.pdf.

[4] U.S. Environmental Protection Agency, 1997a. Mercury Study Report to Congress, Volume II: An Inventory of Anthropogenic Mercury Emissions in the United States. EPA-452/R-97-004.

[5] Minnesota Department of Health, Fish Consumption Advice. http://www.health.state.mn.us/divs/eh/fish/index.html.

[6] Mahaffey, K., U.S. Environmental Protection Agency, 2004. Presentation at National Forum on Fish Contaminants, http://www.epa.gov/waterscience/fish/forum/2004/presentations/monday/mahaffey.pdf.

[7] Minnesota Pollution Control Agency, 1999. Report on the Mercury Contamination Reduction Initiative Advisory Council's Results and Recommendations. www.pca.state.mn.us/mercury.

[8] Minnesota Pollution Control Agency, 2004. Estimated Mercury Emissions in Minnesota for 1990, 1995 and 2000: March 2004 Update. http://www.pca.state.mn.us/publications/reports/mercury-emissionsreport-0304.pdf.

[9] Minnesota Pollution Control Agency, 1999. Report on the Mercury Contamination Reduction Initiative: Advisory Council's Results and Recommendations.

[10] Minnesota Pollution Control Agency, 2002. "Evaluating Voluntary Agreements" from Mercury Reduction Program Progress to the Minnesota Legislature.

[11] Minnesota Pollution Control Agency, 2002. Mercury Reduction Program Progress Report to the Minnesota Legislature.

[12] Minnesota Pollution Control Agency, 1999. Report on the Mercury Contamination Reduction Initiative Advisory Council's Results and Recommendations

[13] Data from progress reports submitted to the Minnesota Pollution Control Agency by voluntary agreement participants, www.pca.state.mn.us/air/mercury.html.

[14] Minnesota Pollution Control Agency, 2004. Estimated Mercury Emissions in Minnesota for 1990, 1995 and 2000.

[15] Xcel Energy 2004. Sherburne County (Sherco) Plant. http://www.xcelenergy.com/XLWEB/CDA/0,get%20this,1-1-1_1875_4797_4014-3642-0_0_0-0,00.html

[16] Minnesota Pollution Control Agency, 2004. Estimated Mercury Emissions in Minnesota for 1990, 1995 and 2000.

[17] This figure is calculated by adding the direct emissions indicated from progress reports from Xcel Energy (35 lbs/yr), Minnesota Power (57 lbs/yr), North Star Steel (2 lbs/yr), MCES (78 lbs/yr) and WLSSD (10 lbs/yr), divided by 3,638 (2000 total estimate).

[18] Minnesota Pollution Control Agency, 2004. Estimated Mercury Emissions in Minnesota from 1990, 1995, and 2000: March 2004 Update.

[19] Minnesota Pollution Control Agency, personal communication, 2004.

[20] Comments of Commissioner Corrigan, Minnesota Pollution Control Agency, June 2, 2004. EPA Air Docket ID No. OAR–2002–0056 (Proposed National Emission Standards for Hazardous Air Pollutants, and, in the Alternative, Proposed Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units).

[21] NESCAUM, 2003. Mercury emissions from coal-fired power plants: The case for regulatory action.
[22] NESCAUM, 2003. Mercury emissions from coal-fired power plants: The case for regulatory action.
[23] U.S. Environmental Protection Agency, 2003. Performance and cost of mercury and multipollutant emission control technology applications on electric utility boilers. Prepared for Office of Research and Development. EPA-600/R-03-110.
[24] M.J. Bradley and Associates, 2004. *Environmental Energy Insights.* Volume VII, Issue 1.
[25] Massachusetts Final regulatory revisions to 310 CMR 7.29 at http://www.mass.gov/dep/bwp/daqc/files/regs/hgreg.pdf.
[26] Massachusetts Department of Environmental Protection, 2004. Fact Sheet: Mercury Emission Limits for Coal-fired Power Plants at http://www.mass.gov/dep/bwp/daqc/files/regs/hgfact.pdf.
[27] Commonwealth of Massachusetts Executive Office of Environmental Affairs, Department of Environmental Protection, Bureau of Waste Prevention Division of Planning and Evaluation, May 2004. Response to Comments for Proposed Amendments to 310 CMR 7.00 et seq.: 310 CMR 7.29 – Emission Standards for Power Plants at http://www.mass.gov/dep/bwp/daqc/files/regs/hgrtc.pdf.
[28] Wisconsin Natural Resources Board, 2004. Authorizing Statutes ss. 227.11(2) (a) and 285.11 (9). http://dnr.wi.gov/org/aw/air/reg/mercury/AM-27-01signed.pdf.
[29] All data are from http://www.epa.gov/triexplorer/. Electric utilities began reporting mercury to the TRI after the threshold for reporting mercury was lowered in 2000. Taconite facilities are not required to report mercury emissions to the TRI.

Izaak Walton League of America, Midwest Office
1619 Dayton Avenue, Suite 202
St. Paul, Minnesota 55104
This report is also available at www.iwla.org/cleanair.