Solar Energy:
Potential Engine for Economic Growth in Milwaukee

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Executive Summary

Southeastern Wisconsin, where Milwaukee is located, is the population center of the state as well as a major manufacturing hub of the country. Milwaukee serves as Wisconsin's economic engine, with two of every three jobs located in the metropolitan Milwaukee area. However, this region has recently lost manufacturing jobs to lower cost regions or to off-shore countries. In addition, the recent severe economic downturn has accelerated the job loss rate in this region and in the City of Milwaukee. This region needs new directions to create sustainable jobs in the manufacturing sector. Solar energy fits the global and national trends of reducing carbon dioxide foot print. Industries manufacturing solar power based products or providing solar power related services have the potential to create sustainable and decent wage jobs for the City and the region. The Milwaukee Shines Solar Program is an excellent channel to promote and attract the solar energy related industry to Milwaukee.

The purpose of this white paper is to propose four solar showcase projects which will educate the general public about the exciting technologies and their applications to solar energy. These projects will also point out that with the right incentive and further R&D, these demonstrated technologies and applications can be easily manufactured in the City of Milwaukee and create job opportunities. The selected showcase projects are (1) Solar PV Integrated with Energy Storage, (2) Solar Thermal Systems, (3) Solar Refrigeration, and (4) Solar Fuel.

The Solar PV Integrated with Energy Storage project will demonstrate that with proper design, solar energy, an intermit energy in nature, can be harnessed as a reliable source or energy. Solar Thermal Systems and Solar Refrigeration projects will show that solar energy can both warm and cool the environment without any electricity. The Solar Fuel project will demonstrate the potential for solar energy to produce more efficient regular fossil fuel. These four show case projects will demonstrate that these technologies can be converted into commercial products which will not only benefit the environment, but have significant local job creating potential. One example is the battery used in the first project will be manufactured by ZBB, a local company based in Menomonee Falls, WI.

Solar PV Integrated with Energy Storage

As part of the demonstration project, an integrated system of solar PV and energy storage can be installed. The energy storage can be charged and discharged to provide power to the local load or trade power with the utility grid. A configuration of this system is shown in figure below. The PV power can be used to supply the local load. A portion of power will be stored in energy storage to be used at peak load or during night time. Other benefits of the system include:

Shifting the peak demand since the maximum PV generation occurs at noon and peak demand occurs in the late afternoon.

Storage of PV energy as well as low cost utility energy during weekends and holidays

Storage of energy in the battery with nighttime utility power.

Operator controlled load by combining load, PV generation, and energy storage.

Improving power quality for the utility customers.

The most suitable energy storage device is zinc-bromide energy storage manufactured by ZBB Energy, based in Menomonee Falls, WI. It is an advanced high energy density flow battery that uses zinc electrolyte in the battery chemistry. Zinc bromide energy storage devices are flowing electrolyte battery generally suitable for large scale power utility, vehicular and industrial applications with energy storage requirement of 50 kWh and above. It can exceed 2000 full charge and discharge cycles during its operating lifetime compared with 750 cycles for conventional lead acid batteries. It is capable of full discharge (100% of stored energy) without any damage to the battery. Its energy density is in the range of 65–84 Wh/kg and it can operate at a wide range of operating temperature without degradation. The materials of the components can be made entirely with plastic to reduce costs and provide readily for recycling or disposal. In addition, it uses a low toxicity electrolyte and recyclable plastic battery stacks compared with more toxic lead and sulphuric acid.

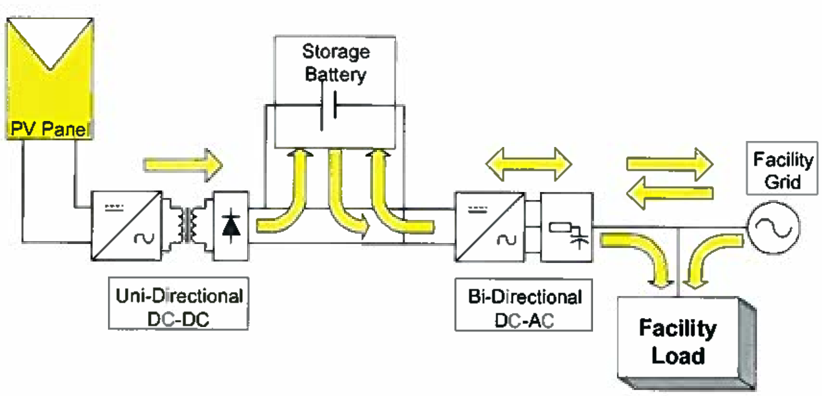


Figure 1. Configuration of the proposed PV system integrated with zinc energy storage.

All parts for the proposed system can be manufactured in Milwaukee. PV modules can be manufactured by many companies in the city if the silicon material is available. All the power conditioning circuitry can be designed and manufactured by Milwaukee area companies including Eaton Corporation and Rockwell Automation. The energy storage is manufactured by ZBB Energy. Commercializing the proposed system will create job opportunities in the Milwaukee area.

Solar Thermal System

As a part of this demonstration project, a solar water heating and solar space heating system will be installed. For water heating system, a flat-plate collector will be installed on the roof and a water storage system will be placed in the basement. An indirect active circulation system will be used since the water may freeze in the collector. An antifreeze heat transfer fluid will be used to heat the water. It will be pumped through the solar collector and will warm up the water in the tank. An additional heating stage may be installed to increase the water temperature at the output. The configuration of this system is shown in Figure 2. This system is very beneficial for homes in the cold region of the country such as Wisconsin. Almost all of the system components can be made by Milwaukee-based companies.

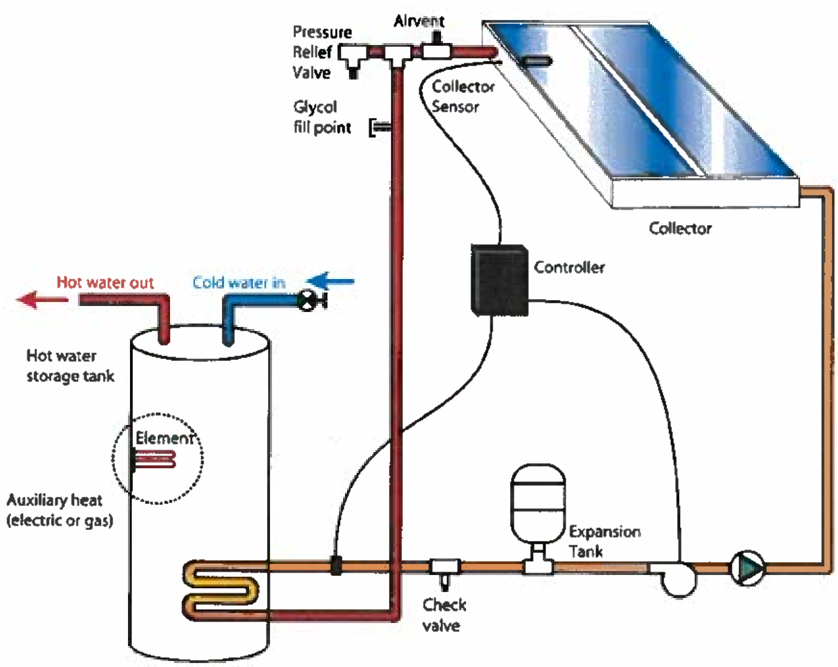


Figure 2. Configuration of the indirect active solar hot water system to be installed.

A portion of the solar collectors installed will be used for space heating. A liquid-based active space heating is considered for this demonstration since it can easily be integrated with water heating system. A controllable fan will drive air through the heat transfer system shown above to adjust the space temperature.

Solar Refrigeration

There's a global scramble to drive down emissions of carbon dioxide: the electricity to power just refrigerators in the U.S. contributes 102 million tons annually. Solar refrigeration can also be inexpensive and it would give the electric grid much-needed relief. Electricity demand peaks on hot summer days—150 gigawatts more in summer than winter in the U.S. (A gigawatt equals on billion watts.) That's almost 1.5 times the generating capacity of all the coal-fired power plants west of the Mississippi River. Further, solar is plentiful. The solar energy hitting 54 square feet (five square meters) of land each year is the equivalent of all the electricity used by one American household, according to data from the National Renewable Energy Laboratory and Energy Information Administration, both part of the U.S. Department of Energy.

Outside the US, according to the World Bank, there are 1.6 billion people world wide do not have access to refrigerator due to the lack of electricity. Without refrigeration, food-borne diseases spread more rapidly. Farmer can't store their crops in hopes for getting a better price. In many places, the countries do not have resources to build the grid infrastructure to spread the electricity to the remote villages. Solar refrigeration will help improve the health and local economy. The global demand and the potential market for solar refrigeration based products are enormous.

Making cold out of hot is easier than one might think. The key is the energy exchanged when liquids turn to vapor and vice versa—the process that cools you when you sweat. By far the most common approach, the one used by the refrigerator in your house, uses an electric motor to compress a refrigerant—say, Freon—turning it into liquid. When the pressure created by the compressor is released, the liquid evaporates, absorbing heat and lowering the temperature.

Absorptive chillers like solar refrigerators use a heat source rather than a compressor to change the refrigerant from vapor to liquid. The two most common combinations are water mixed with either lithium bromide or ammonia. In each case, the refrigerating gas is absorbed until heat is applied, which raises the temperature and pressure. At higher pressure, the refrigerant condenses into liquid. Turning off the heat lowers the pressure, causing that liquid to evaporate back into a gas, thereby creating the cooling effect.

As with most technologies, the efficiency of such absorptive refrigeration depends on the degree of engineering (and expense) brought to bear. With advancement in Solar refrigeration technology, solar refrigeration soon can co-exist with or even replace the common electrical refrigeration. Economic and environmental benefits which can be derived from this technology also bold well for the long term future of this technology. Currently, there is very few commercially available solar power driven refrigerators on the market. However, the world wide demand for the solar refrigeration based products can be very significant when the technology becomes more mature. Our solar refrigeration demonstration project will construct a solar powered refrigeration to highlight this technology and point out that with right incentive and further R&D, solar refrigeration based products can be manufactured in the City of Milwaukee and create job opportunities.

Another way to use solar for cooling is through the solar solid desiccant cooling. A solar desiccant cooling system is attractive because it is environmentally benign and offers significant energy saving potential. With the establishment of the Montreal Protocol to phase out the use of certain fluorocarbons, the desiccant cooling can be used as an alternative to the conventional vapor compression air conditioning without any impact to the ozone layer. The desiccant cooling system can provide up to 100% fresh air to the conditioned space and the desiccants can also remove some indoor air pollutants, both of which may greatly improve the indoor air quality. In a solar desiccant cooling system, only solar energy and little electricity used for fans, pumps and controls are consumed. The reduced electrical energy requirement may reduce the consumption of the fossil fuels and relieve the greenhouse effect and the uprising of the sea level. Solar energy is clean and renewable. Furthermore, the cooling load and the availability of solar radiation are approximately in phase.

Desiccant cooling systems take in air from outside or from the building, dehumidify it with a desiccant, pre-cool it by exchange of sensible heat, and then evaporatively cool it to the desired state. The desiccant used in the system is usually recycled by regeneration. If the desiccant is regenerated with **solar energy**, this system is called **solar desiccant cooling system**. There are two basic cycles for solar desiccant cooling. One is the ventilation cycle and the other is the recirculation cycle. In a ventilation cycle, it takes ambient air into a rotating desiccant dehumidifier where moisture is adsorbed. The temperature of air increases because of the energy released during the adsorption process. The air is then sensibly cooled and evaporatively cooled and introduced into the conditioned space. In contrast, the air from the building is first evaporatively cooled, then passed through the sensible heat exchanger where it recovers heat of adsorption from the supply air. Next it is heated with solar energy and the hot air is used to regenerate the desiccant. A recirculation cycle is only a variation of the ventilation cycle. The same components are used, but the air from the conditioned space is re-circulated and ambient air is used only for regeneration in the recirculation cycle.

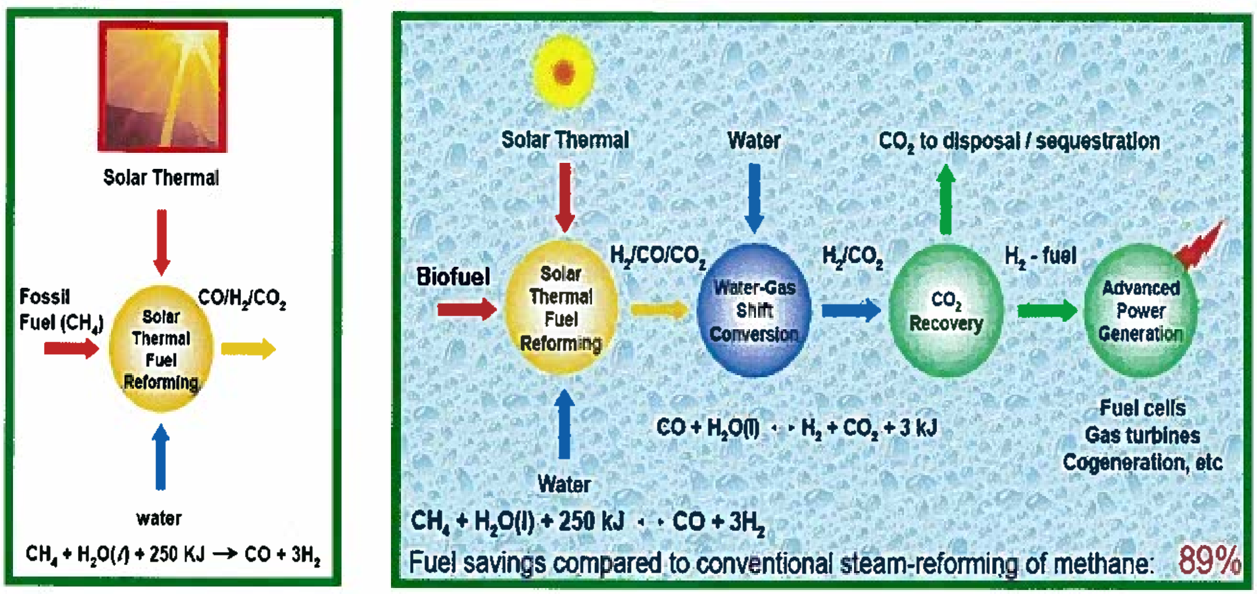
A small scale solar desiccant cooling system will be constructed to demonstrate the feasibility of this technology.

Solar Fuel

The objective of this project is to develop and demonstrate a decentralized Solar and Bio Combined Sustainable Energy System for transportation engine and micro turbine fuel application (Biomass & solar-to-Hydrogen enriched Biogas) and fuel cell hydrogen application (Biomass & solar-to-Hydrogen). The intention is to promote the utilization of eco-friendly bio and solar energy resources at a massive scale and to the maximal extent in view of reducing greenhouse gas emission and building up recycling-oriented society through the effort of intensive research into the bio and solar combined sustainable energy system.

As we know, the need for reducing pollutant emissions and utilizing available energy resources, such as bio and solar energies, more efficiently has led to increased attention towards alternative energy solutions. "And in the years ahead, technology will allow us to create entirely new sources of energy in ways earlier generations could never dream (from Bush's speech on April 27, 2005)." As sustainable energy systems coming into use, it becomes increasingly important to investigate the implementation of these new systems into the conventional energy systems i.e. how bio and solar energy system can function as a complement to existing transportation engine and micro turbine fuel and fuel cell hydrogen supplies. The issue to be solved when using bio and solar energy system is the impact of fluctuating environmental conditions, which often requires energy storage and even complementary energy conversion. The solution is the storage of hydrogen enriched biogas for on-time use in transportation engines and micro turbines or pure hydrogen for on-time use in fuel cell systems.

The "biogas", which mainly consists of CH_4 and CO_2, is a medium-or low-calorific gas. There exist the problems of low energy density and combustion inability when it is directly used as the



(a) (b)

Fig. 1 The biogas-solar upgrading to hydrogen-rich biofuel and pure hydrogen processes

fuel of internal engines and micro turbines. This is resulting from the low methane concentrations and higher ignition energy and low flame speed of methane. Whereas, hydrogen not only is a clean type fuel but also has excellent combustion properties, such as low ignition energy (1/10 of that for gasoline), high flame speed (9 times that of gasoline), very broad flammability range (allowing unique potential for oxides of nitrogen (NO_x) emission control through ultra-low levels using very lean strategy and exhaust gas recirculation EGR). Therefore, it is our intention to upgrade the biogas to high-calorific hydrogen enriched biofuel by input renewable solar thermal energy through partial methane reforming process (as shown in Figure 1 (a)). It is also completely compatible with existing energy infrastructure. Besides, this sustainable energy system can easily satisfy the needs of future hydrogen energy system by complete methane reforming and hydrogen separating and filtering shown in Figure 1 (b). Figure 2 illustrates the demonstration for the solar enhanced bio-fuel gas for the automobile application.

Fig. 2 Solar-upgraded hydrogen-rich biofuel for automobile

The products of such hybrid processes are cleaner fuels whose quality has been solar-upgraded: Their calorific value is increased by the solar input in an amount equal to the enthalpy change of the reaction. Increased energy content means extended fuel life and reduced pollution of the environment.