



OIL-POWERED THERMO-PHOTO-VOLTAICS (TPV) JUNE 1999

WHAT IS TPV?

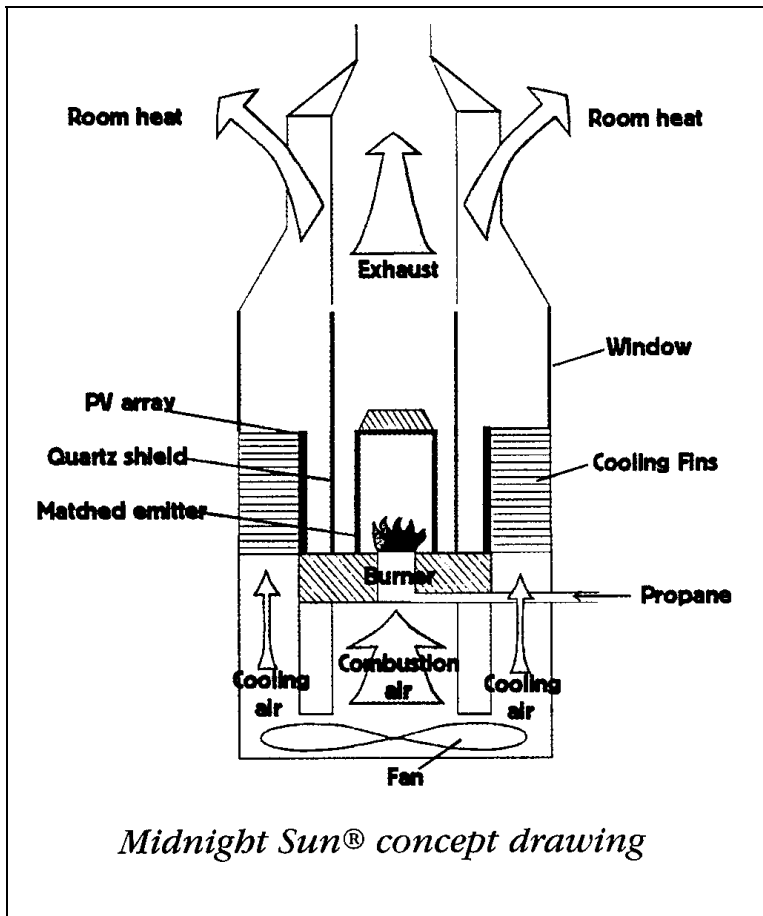
TPV is one of several new oil heating technologies that can drastically improve the way we use fuel oil in homes, and assure a bright future for home heating oil. **TPV - thermophotovoltaics** - uses the radiation from flames to generate electric power and it is in its early stages of development. The military has worked on this technology for more than 30 years, but recent advances in photocell materials is expected to produce practical and efficient TPV power generation for oil burners. By developing a specially designed combustion chamber containing TPV cells, conventional oil furnaces and boilers can produce substantial quantities of electric power for use in the home. The combined generation of heat and electricity represents an important breakthrough in “micro-cogeneration” systems for residential and commercial use. TPV systems can offer important cost, environmental, reliability, and performance advantages over conventional electric power produced by utilities.

HOW DOES IT WORK?

Solar powered Photovoltaic (PV) cells have been used for many years to generate electric power from the sun's radiation. **TPV** uses specially developed photo cells to generate electric power from the radiation produced by flames. The main components of a TPV system are:

- a **burner** to produce the flame
- an **emitter** that produces infrared radiation that is filtered or tuned to the TPC cells
- **photocells** that receive the radiation (at a specific wavelength(s)) and produces electricity
- **heat recovery** equipment to preheat the air and to transfer the by-product heat for space heating and water heating applications.

The diagram that follows for a TPV product shows schematically how the electric generation cells can be incorporated into a heating system to produce electricity and heat. Some of the flame's radiation makes electric power and most of the by-product heat (about 85%) is recovered - producing high overall efficiency.



The flame heats the specially designed emitter which releases radiation at a certain frequency. This radiation then passes through a quartz shield onto the PV array. The PV array generates electric energy for household uses. Cooling air circulates around the PV array and also picks up the residual heat from the flame for room heating.

A wide range of oil powered furnaces and boilers can be envisioned where the flame, emitter, and PV array are all integrated into a uniquely configured “combustion chamber”. Tuning the emitter to produce radiation with a frequency that can be absorbed by the PV array to produce electric power is a key challenge of TPV systems. Also, higher temperature flames

(with air preheating) are required for maximum electric efficiencies of 15% to 20%.

HOW MUCH ELECTRICITY CAN BE GENERATED BY AN OIL FLAME?

The electric power output depends on several key parameters including the oil firing rate, the “matching” of the emitter and PV array, and the temperature of the flame. Radiation increases rapidly as the flame’s temperature increases (as a function of temperature raised to the 4th power). Therefore, air preheating is necessary to reach very high electric efficiencies.

Research indicates that flames someday will produce between from 3 to 4 watts of electric power per square centimeter of PV surface area. Advanced arrays using multi-frequency cells may produce between 5 and 6 watts/sq cm. What does this mean for a convention-size oil burner? For a cylindrical combustion chamber that is 12 inches in diameter and 12 inched long, the TPV output could reach more than 10,000 watts of power. This is adequate powering for most homes.

One reason for the strong interest in Thermal PV is that these electric generation rates are **233 times higher than comparably sized solar PV cells**. This means that most of a home electric needs can be supplied by the oil burner - both day and night.

The table that follows shows the total electric power that can be generated in homes each year for a range of TPV system efficiencies.

Fuel Oil Use: 850 gallons per year
Elec. Use (average): 7,071 Kwh per year (based on US Dept. of Energy data)

TPV Electric Energy Generation (Kilowatt Hours per year)				
	<u>Electric Efficiency of TPV</u>			
	5%	10%	15%	20%
TPV Electricity	1700	3400	5100	6800
% of Total	24%	48%	72%	96%

As the efficiency of the TPV electric generation increases from **5% to 20%**, the percentage of the total electric energy used in a typical home that is supplied by TPV increases from **24% to 96%**, while the oil burner operates to meet the space heating needs of the home. Oil powered TPV can someday generate a substantial fraction, or all of the electric needs of homes. In fact, the production of electricity by utility power plants can be replaced by highly efficient TPV units in homes.

ECONOMICS OF OIL POWERED TPV

A brief summary of the cost of generating electric energy in homes using oil powered TPV and a comparison to current costs follows.

Oil Price: **\$0.85** per gallon (the average price of oil in 1998),
 TPV elec efficiency: **15%**
 Heat Losses: **attributed to furnace operation** (not the TPV generator),
 Electric Use: **7,071** Kilowatt-hours (for the average home in the Northeast)

- the cost of TPV-generated electricity is only **\$0.021 per kilowatt-hour**
- this is **6 TIMES** lower than the average price of electricity purchased from utilities in New England and the Mid Atlantic states (\$0.124 per kilowatt-hour).
- Projected cost savings are **\$525 a year** for an oil TPV unit
- **Payback** within **3 years** is produced If the added cost of the TPV system is \$1,575 or less.

Typical cost savings each year were evaluated for a home using 850 gallons of oil, and generating 5,100 Kilowatt-hours a year of TPV electricity (15% electric efficiency):

CASE 1: TPV Cogeneration System (5100 Kwh)

850	Gallons of Oil for space & water heating
<u>124</u>	<u>Gallons of Oil for Electricity (5100 Kwh)</u>
974	Total Gallons of oil
X 0.85	\$ per Gallon
\$ 828	per year for heating and 5100 Kwh
+244	for Utility Electricity (7071 - 5100 @\$0.124 /Kwh)
\$1,072	Total heating and Electric Cost

CASE 2. Oil Heating and Utility Electric Power

\$ 722	for 850 gallons of oil @ \$0.85/Gallon
<u>877</u>	<u>for 7,071 Kwh @ \$0.124/Kwh</u>
\$1599	Total heating and Electric Cost

SAVINGS WITH TPV = \$1,599 - 1,072 = \$527 / YEAR (33%)

In addition to the cost savings to home owners, the TPV system uses an addition 124 gallons of oil a year to generate electricity which is a 14% increase in oil use.

ADVANTAGES OF OIL POWERED TPV

A brief summary of some of the important advantages for **homeowners** are supplied by oil powered TPV systems follows:

- **Lower electricity prices** - up to 6 times less than utility power
- **Highly efficient operation** - exhaust heat is used for space heating (and cooling)
- **Simple design and operation** - no moving parts to break down as with an engine-generators or electric power plants
- **Improved reliability** - requires no power transmission lines to the home
- **Attractive economics** - electric costs lowered by up to 75%, and combined electric and heating costs are lowered by 33%
- **Lower Air Pollution** - key pollutants are lowered by up to 90% including particulates, nitrogen oxides, sulfur oxides, and greenhouse gases.

The **oil heat industry** also benefits from the use of TPV systems in many ways including:

- **New oil equipment sales** to replace conventional equipment with TPV systems
- **Expanded markets for oil heat** into warmer regions
- **Increased sales of fuel oil** to supply electricity, and space heating and cooling
- **Year round use of heating oil** including electric power and cooling
- **Stronger markets for oil use and oil equipment** in residential and commercial buildings
- **Reduced competition from electric utilities** for residential customers and increased conversions to oil heating equipment
- **Rapid expansion of oil** into the new home market

This new technology can stimulate a re-emergence of home heating oil as a premium and highly attractive energy source for homes and commercial buildings, and help to regain and exceed the market share that existed before the 1970s and 1980s. It also gives oil heat a “high-tech” image for more successful competition with other home energy sources.

STATE OF DEVELOPMENT

Currently, oil powered TPV is in its early stages of development. Small scale military applications are now being developed and tested, which includes work by Brookhaven National Laboratory (BNL). The BNL project is using its innovative Fan Atomizing Oil Burner to produce approximately 500 watts of power while firing at only about **0.07** gallons per hour. Advances in TPV cell and emitter designs are on-going, and it is possible that practical oil-powered TPV systems for homes could emerge in the next 5 to 10 years. This can be accelerated by increased research and development projects by the National Oilheat Research Alliance and other industry groups.

Oil powered Thermophotovoltaics is clearly an exciting new technology that, if successful, could offer many important benefits to homeowners and the oil heat industry.

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