



ThermoPhotoVoltaics (TPV) Cogenerating Electricity from Hot Steel

Dr. Lewis Fraas

JX Crystals Inc

Oct 24, 2013

JX Crystals Inc TPV for Electric Power from Hot Steel

Advantages:

High Temperature Source
➤ 1100 C

24 / 7 for great economics

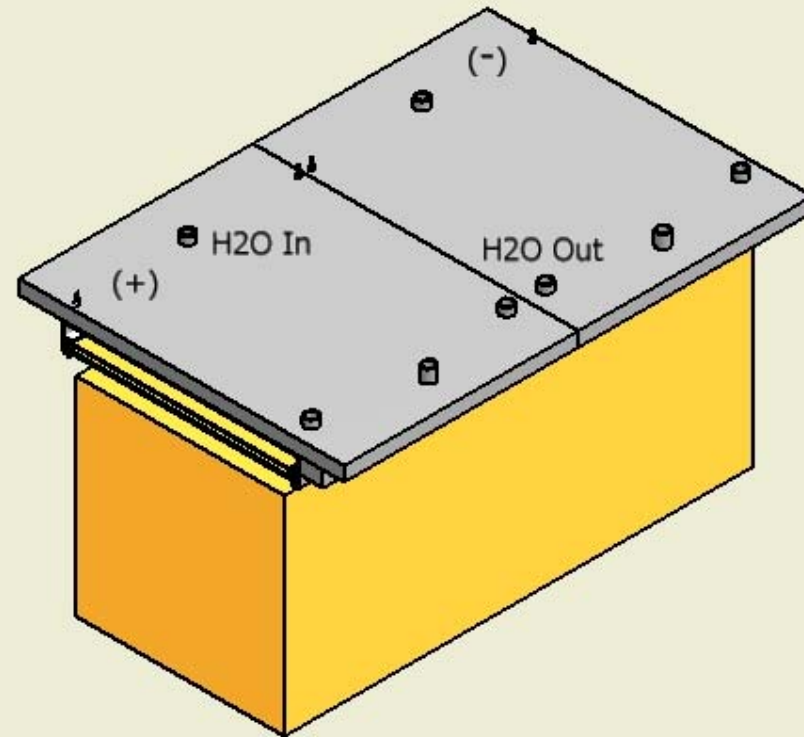
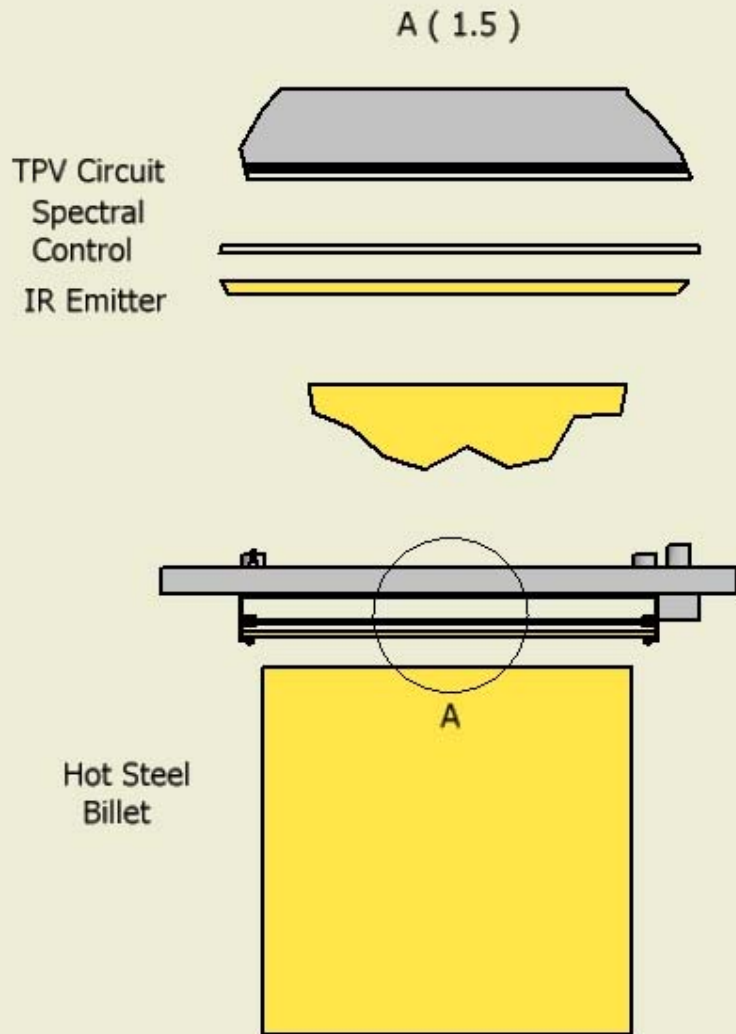
High Power Density
➤ 1 W/cm²

Huge Market
20 MW per steel mill
10 GW world wide

Fast Payback
1.5 years at \$1/W



TPV Generator Assembly



JX Crystals Inc
Patent Pending

Demonstration: Single GaSb Cell Measurement



GaSb cell electric power 1.5 W/cm^2
(referenced to emitter area)

Emitter temperature 1275° C

Spectral efficiency 74%

Cell efficiency 29%

TPV efficiency 21.5%



A Fantastic Opportunity

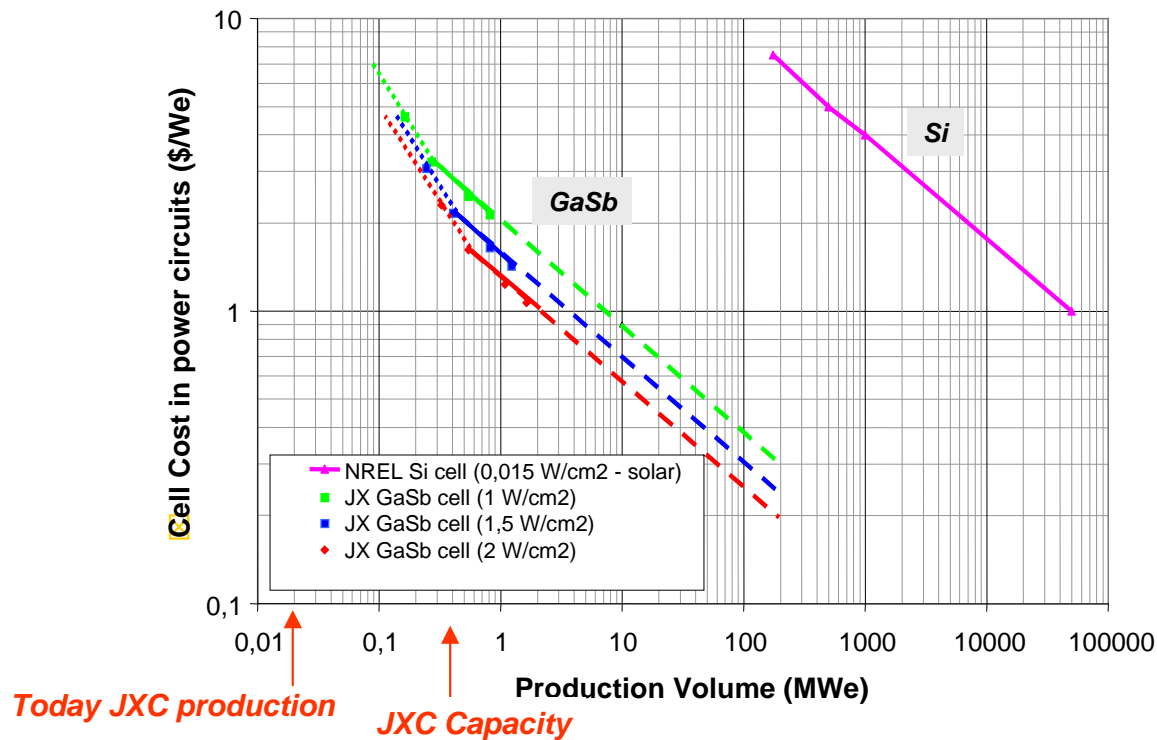


- JX Crystals Inc is unique with the TPV knowhow and equipment for cell and circuit fabrication as well as the TPV patent protection
- Projected Performance

Temperature	Wavelength	Blackbody Energy	Filtered Energy	Cell Electric Power
1500 K (1227 C)	4-12 micron	6.8 W/cm ²	1.7 W/cm ²	
	1.8-4 micron	15.4 W/cm ²	1.5 W/cm ²	
	0.4-1.8 micron	5.9 W/cm ²		1.8 W/cm ² (20% Efficient*)
1400 K (1127 C)	4-12 micron	5.9 W/cm ²	1.5 W/cm ²	
	1.8-4 micron	11.5 W/cm ²	1.2 W/cm ²	
	0.4-1.8 micron	3.4 W/cm ²		1.1 W/cm ² (18% Efficient)

* $1.8 / (1.7 + 1.5 + 5.9) = 1.8 / 9.1 = 20 \%$

Achievable GaSb Cell Costs



Today
10000 \$/kWe



300kWe
2000 \$/kWe



100MWe
300 \$/kWe



Scenario where Midnight Sun TPV Co sells 300 W Flat Hot Steel FHS-TPV generators

Market, Sales, Profit Loss	Phase I		Phase II		
Year	2014	2015	2016	2017	2018
300 W FHS-TPV (#)	Development	500	10,000	20,000	60,000
Production Volume (W)		150,000	3,000,000	6,000,000	18,000,000
Circuit Price per W (\$)		\$3	\$2.5	\$2.0	\$1.5
Circuit Cost per W (\$)		\$5	\$2	\$1.5	\$1
Circuits cost \$ per FHS-TPV		\$1,500	\$600	\$450	\$300
Gross Margin (%)		0%	25%	33%	50%
FHS-TPV Sales		\$0.45 M	\$7.5 M	\$12 M	\$27 M
FHS-TPV GrossProfit (Loss)\$		(\$0.3 M)	\$1.5 M	\$3 M	\$9 M
Investment R&D	\$1.5 M	\$0.7 M	\$0.5 M	\$0.5 M	\$0.5 M
Invest (Equipment & IP)	\$3 M	\$0.5 M	\$1 M	\$1 M	\$2 M
Profit / Loss	(\$1.5 M)	(\$1.0 M)	0	\$3 M	\$9 M
Accumulated Value	\$1.5 M	\$1 M	\$2 M	\$6 M	\$17 M

Investment is \$6 M and accumulated value in 5 years is \$17 M with growing \$B company.

Conclusions

- Thermophotovoltaics (TPV) is complimentary to Solar Photovoltaics but it operates at night and in cold climates
- TPV is ideal for small and large scale Combined Heat & Power and it uses natural gas
- TPV can be used in steel mills to convert waste heat into electricity 24 hrs per day 7 days a week and this is a huge market
- JX Crystals is the world leader in TPV
- JX Crystals IR cells are key to a large number of new applications