



*Thermal Vacuum Power from the Sun*

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**China Solar Cooling Week, Shanghai, 27<sup>th</sup> of March 2015**

*High-Vacuum Flat Solar Thermal Panels for:*

- *air-conditioning*
- *industrial process heat*



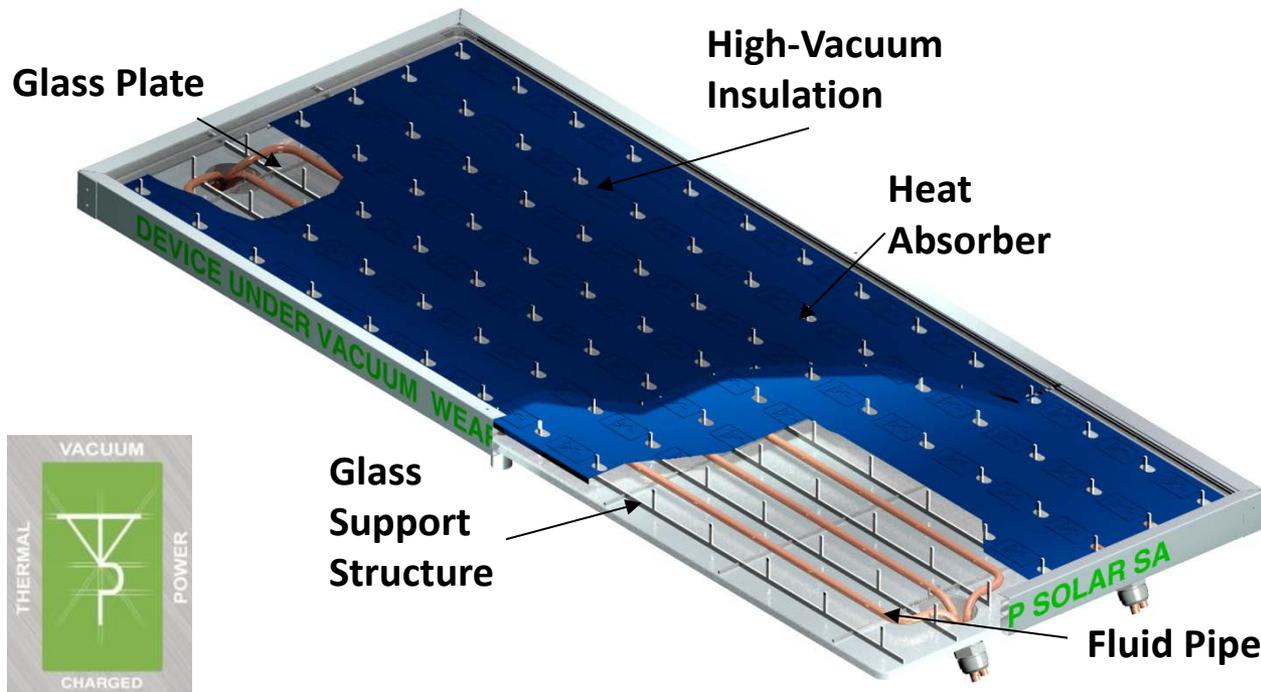
**CHINA  
SOLAR COOLING  
WEEK 2015**



# Thermal Vacuum Power Charged™ Products

## Industry-changing solar thermal panels

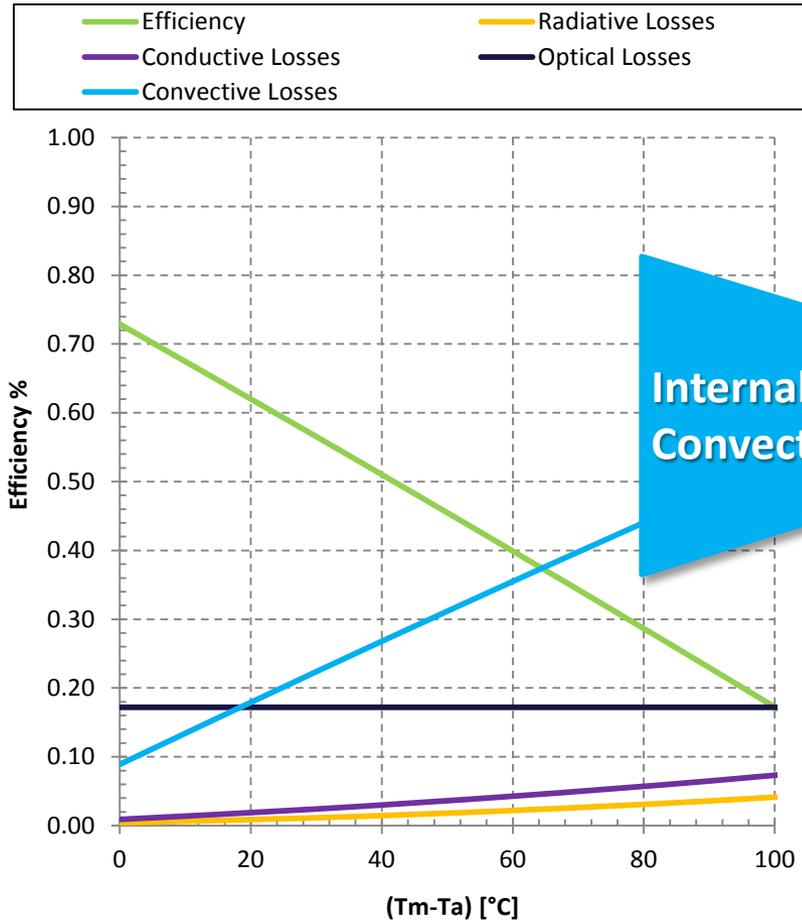
TVP solar thermal panels take full advantage of high-vacuum insulation in a planar layout, achieving high efficiencies up to 200°C without concentration



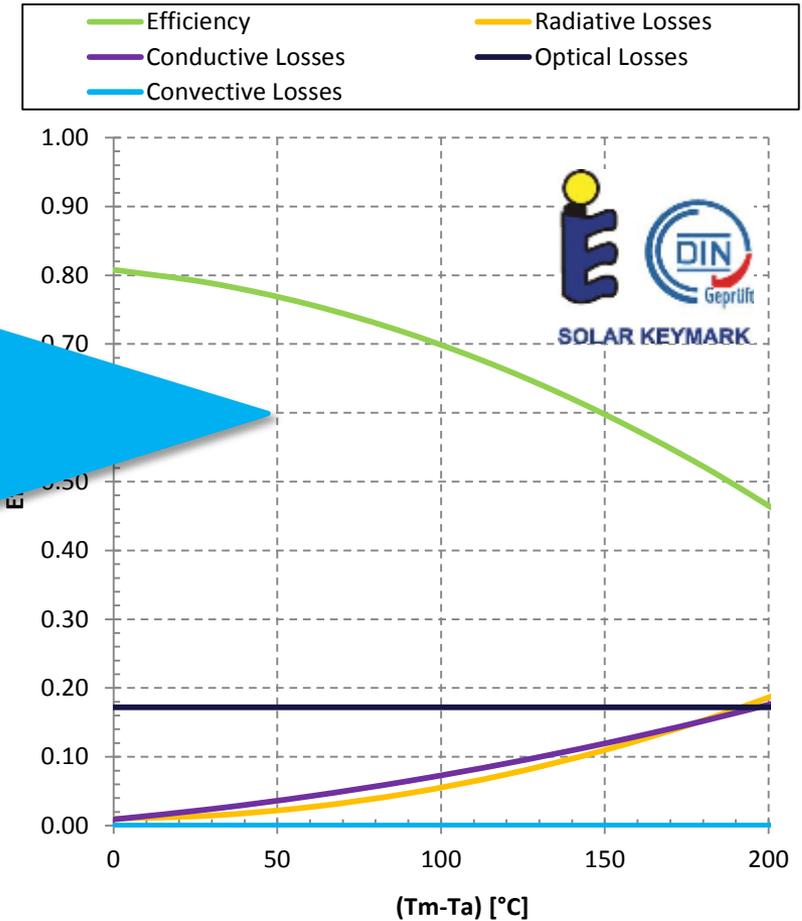
Thermal Vacuum Power Charged™ panels capture both direct and diffuse light maximizing the amount of sun energy converted to thermal. Energy output is increased by at least 30%. TVP Solar owns 11 patents protecting breakthrough core technology, products and manufacturing

# Solar KeyMark Certified Best Performance

Highest efficiency up to 200°C in any light condition thanks to high-vacuum insulation



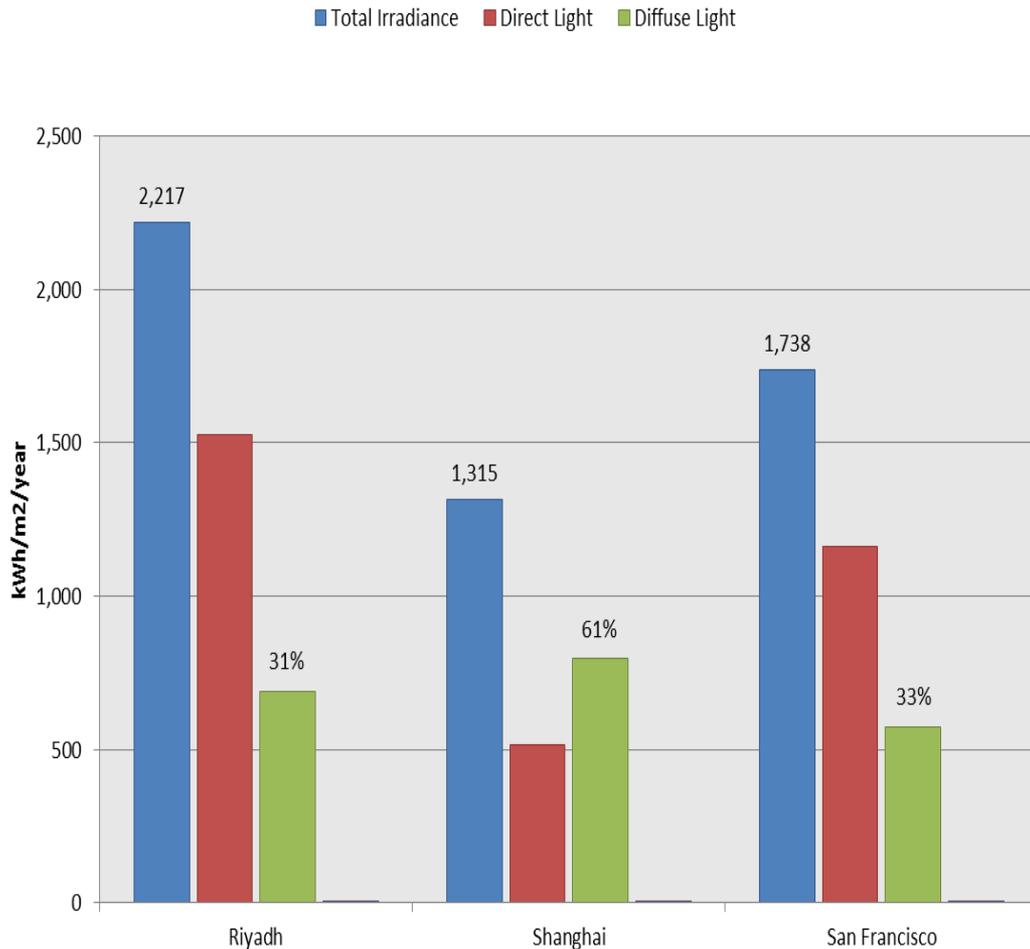
Traditional flat plate fiberglass insulation



TVP Solar flat panels high-vacuum insulation

# Main Differentiating Factor: Diffuse, Polluted Light Capture

Clouds, humidity, dust, pollution, and sand contribute heavily to diffuse light



- Thermal Vacuum Power Charged™ panels capture both direct and diffuse light
- Even in high irradiance locations diffuse light represents a significant portion of annual solar energy input due to clouds and pollution
- Increasing the efficiency of a solar collector by concentration reduces diffuse light capturing by the inverse of the concentrating factor due to optical laws
- Diffuse light also plays a significant role at dawn and at dusk, due to low-angle light scattering, impacting solar field energy production

# Zero Maintenance: No Significant Effect By Dust & Dirt

Uniquely proven in-field with measured results published at IEA SHC Task Meetings

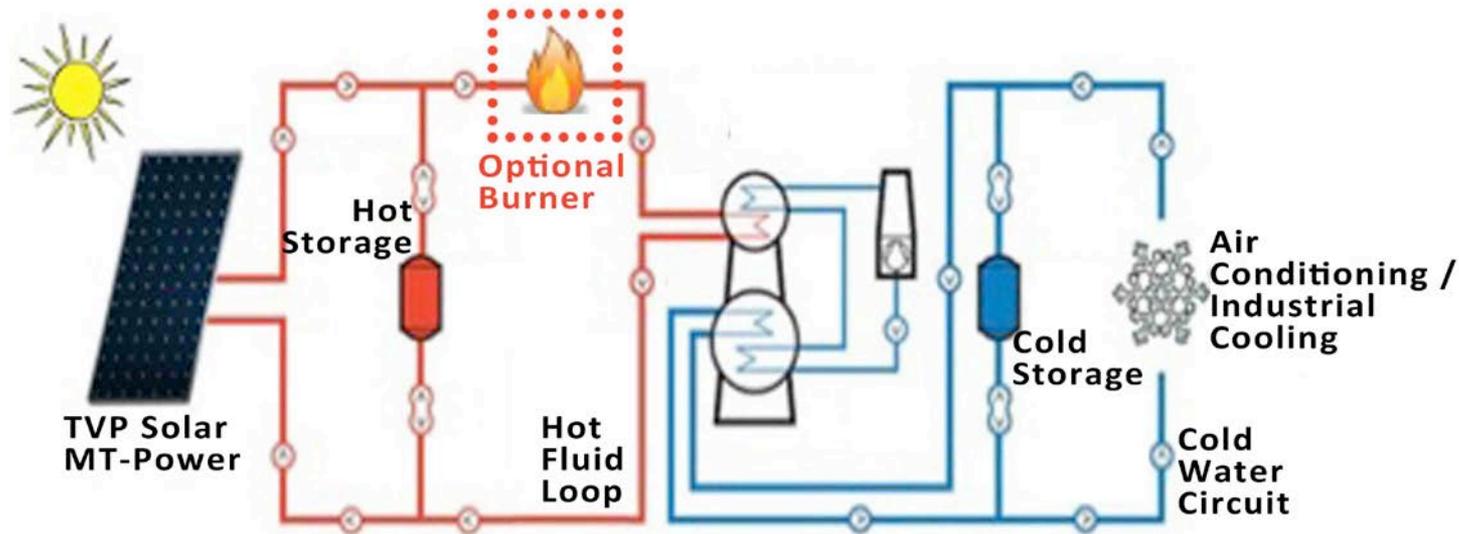
TVP panels do not require precision cleaning due to both direct and diffuse light capture, making them key to supplying solar thermal in hazy, dusty, polluted, humid climates



TVP panels use inexpensive, standard stationary support structures which do not require any maintenance, otherwise mandatory for concentrator tracking systems

# Solar Assisted Air Conditioning: Both 2E & 1E VAM

Driving standard absorption chillers (recommended hybrid configuration for 24/7)



Solar thermal energy feeds an absorption chiller instigating thermodynamic condensation process, then supplying a secondary circuit of cold water into a building

Solar energy covers peak load and most daylight cooling needs; hybridizing with an auxiliary burner using traditional combustible (natural gas, bio-diesel, etc ) for 24/7 smooth operations

- ✓ TVP panels have the highest sun-to-cool peak efficiency: up to 78% @ 180°C (2E VAM), up to 50% @95°C (1E VAM)
- ✓ Optionally providing year-round dual savings: *cooling in summer, heating in winter (with sanitary hot water for free)*
- ✓ Compact stationary solar field with minimum footprint, adaptable to any rooftop

# Energetics: Consistent and Predictable

MT-Power energy production & thermal efficiency depend on irradiance

Global Horizontal Irradiance (GHI)		T <sub>out</sub> (°C)									
		60	95	110	120	130	140	150	165	180	190
<b>2,217</b>	kWh/m <sup>2</sup> /year	1,727	1,528	1,427	1,355	1,279	1,200	1,118	1,034	861	773
<b>2,117</b>	kWh/m <sup>2</sup> /year	1,702	1,502	1,401	1,330	1,255	1,179	1,099	977	852	768
<b>1,988</b>	kWh/m <sup>2</sup> /year	1,557	1,363	1,266	1,297	1,125	1,050	974	857	738	659
<b>1,957</b>	kWh/m <sup>2</sup> /year	1,528	1,333	1,234	1,163	1,090	1,013	935	814	691	609
<b>1,839</b>	kWh/m <sup>2</sup> /year	1,391	1,200	1,104	1,034	966	895	822	712	602	530
<b>1,755</b>	kWh/m <sup>2</sup> /year	1,384	1,184	1,086	1,017	947	875	802	692	583	511
<b>1,638</b>	kWh/m <sup>2</sup> /year	1,281	1,081	983	916	847	776	706	600	496	428
<b>1,529</b>	kWh/m <sup>2</sup> /year	1,187	992	900	836	772	706	641	544	449	389
<b>1,444</b>	kWh/m <sup>2</sup> /year	1,128	932	839	775	710	644	579	484	393	335
<b>1,325</b>	kWh/m <sup>2</sup> /year	1,018	831	745	686	627	569	511	427	347	296
<b>1,208</b>	kWh/m <sup>2</sup> /year	884	706	627	573	520	468	417	343	273	230
<b>1,112</b>	kWh/m <sup>2</sup> /an	811	637	559	508	457	407	359	290	228	190

# Masdar City, Abu Dhabi, UAE: TVP Supplies up to 180°C

TVP  SOLAR



# Masdar City, Abu Dhabi, UAE: Case Study Results

## Case study 1: Solar Air Conditioning with double stage absorption chiller

Operating Year: 2014	Input Energy on Collector Plane (kWh/m <sup>2</sup> /day)	Solar Field Average Daily Energy Produced (kWh/m <sup>2</sup> /day)	Solar Field System Efficiency	Solar Field Average Daily Energy Produced (kWh/day)
<i>January</i>	4.89	2.09	43%	87.88
<i>February</i>	5.45	2.24	41%	94.02
<i>March</i>	5.52	2.28	41%	95.58
<i>April</i>	5.73	2.44	43%	102.34
<i>May</i>	4.74	1.74	37%	72.98
<i>June</i>	4.46	1.73	39%	72.58
<i>July</i>	4.68	1.84	39%	77.26
<i>August</i>	4.97	2.22	45%	93.19
<i>September</i>	5.52	2.48	45%	104.02
<i>October</i>	5.70	2.20	39%	92.59
<i>November</i>	4.87	2.07	42%	86.78
<i>December</i>	4.81	2.03	42%	85.29
<b>Month Average</b>	<b>5.11</b>	<b>2.11</b>	<b>41%</b>	<b>88.71</b>
<b>Year Total</b>	<b>1,865.56</b>	<b>770.92</b>	<b>41%</b>	<b>32,378.63</b>

- Panels remained uncleaned throughout measurement year 2014
- Masdar SAC field by TVP has been in continuous operation since February 2012

# Aramco, Dhahran, KSA: TVP Supplies up to 180°C

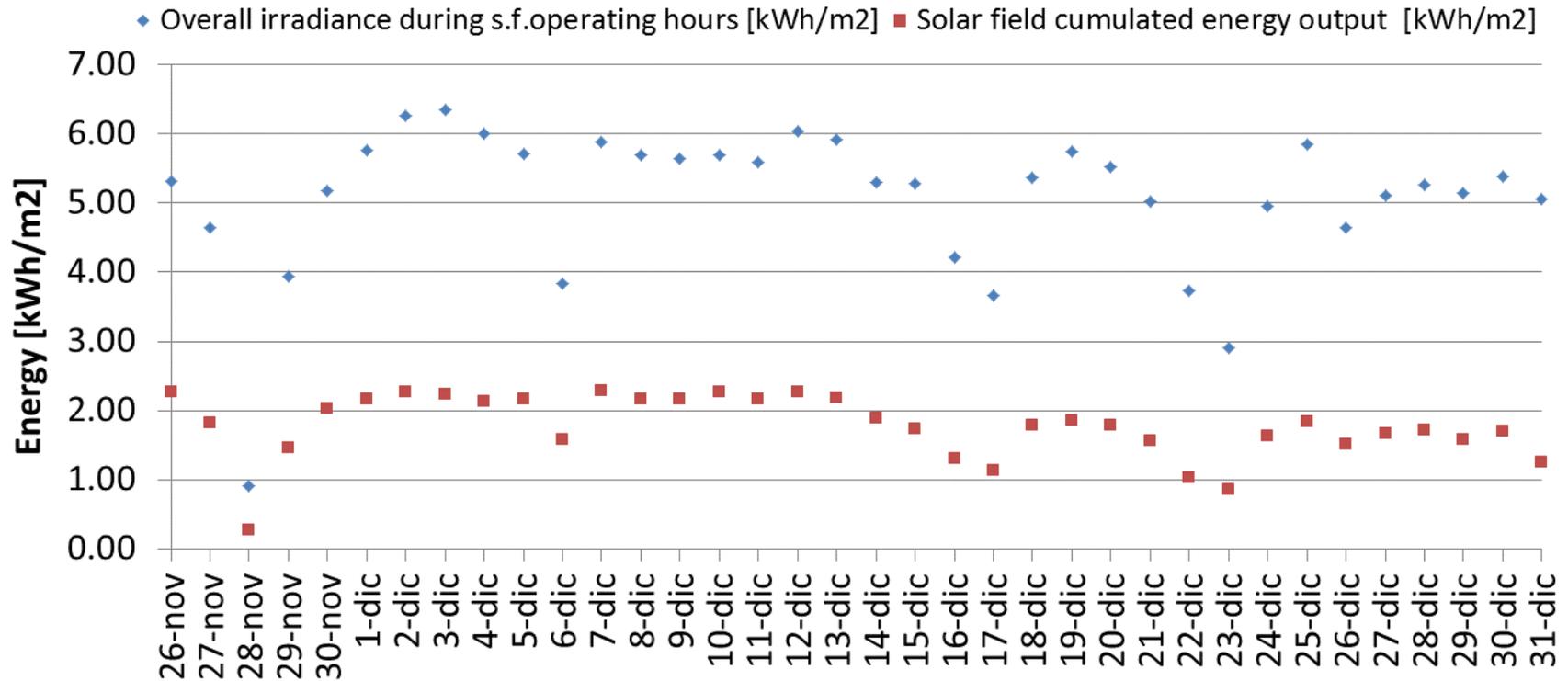
TVP  SOLAR



# Aramco, Dhahran, KSA: Case Study Preliminary Results

## Case study 2: Solar Air Conditioning with double stage absorption chiller

### Solar Field Thermal Energy Production/m<sup>2</sup>



- Panels have not been cleaned since commissioning
- Commissioned Oct 2014

# TVP Solar: New Developments for MT-Power

New release 4.3 for volume production introduced in Q4 2014



## Improvements of new MT-Power 4.3 vs 3.22 currently installed in Aramco

- ✓ Doubled the panel size: 2m<sup>2</sup> vs 1m<sup>2</sup>
- ✓ Reduced weight: 25kg/m<sup>2</sup> vs 42kg/m<sup>2</sup> (-40%)
- ✓ New absorber design: 2 parallel flows (implementing patented return flow under high-vacuum) vs meander pipe
- ✓ New manufacturing of parts: molded vs laser cut

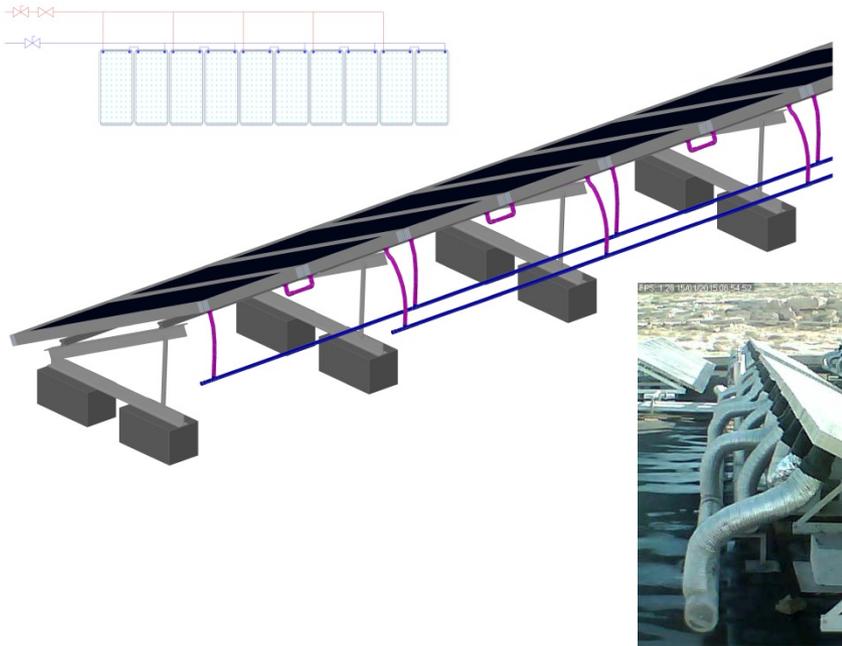
# TVP Solar New Solar Field Layout: Embedded Return Piping (i)



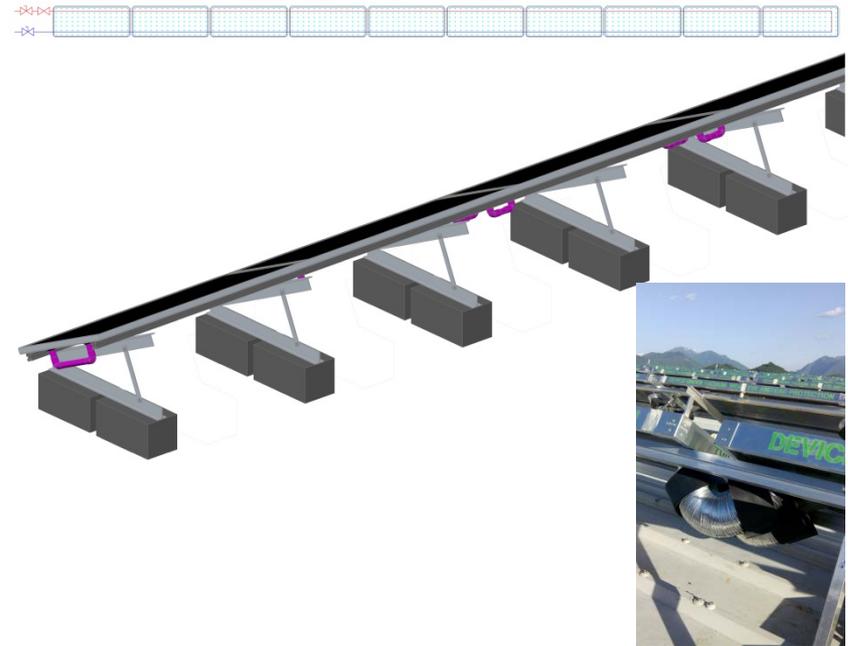
# TVP Solar New Solar Field Layout: Embedded Return Piping (ii)

## Simplified solar field balance of system

v.3.22 @ Masdar



New v. 4.3



### Benefits of new MT-Power 4.3:

- ✓ No external piping on panel strings and lower solar field balance of system cost
- ✓ Easier, quicker and cheaper installation
- ✓ Lower maintenance cost
- ✓ Higher system performance due to better insulation of return pipe via high-vacuum

# TVP Solar New Solar Field Layout: Embedded Return Piping (iii)



# Conclusions & Take-Aways

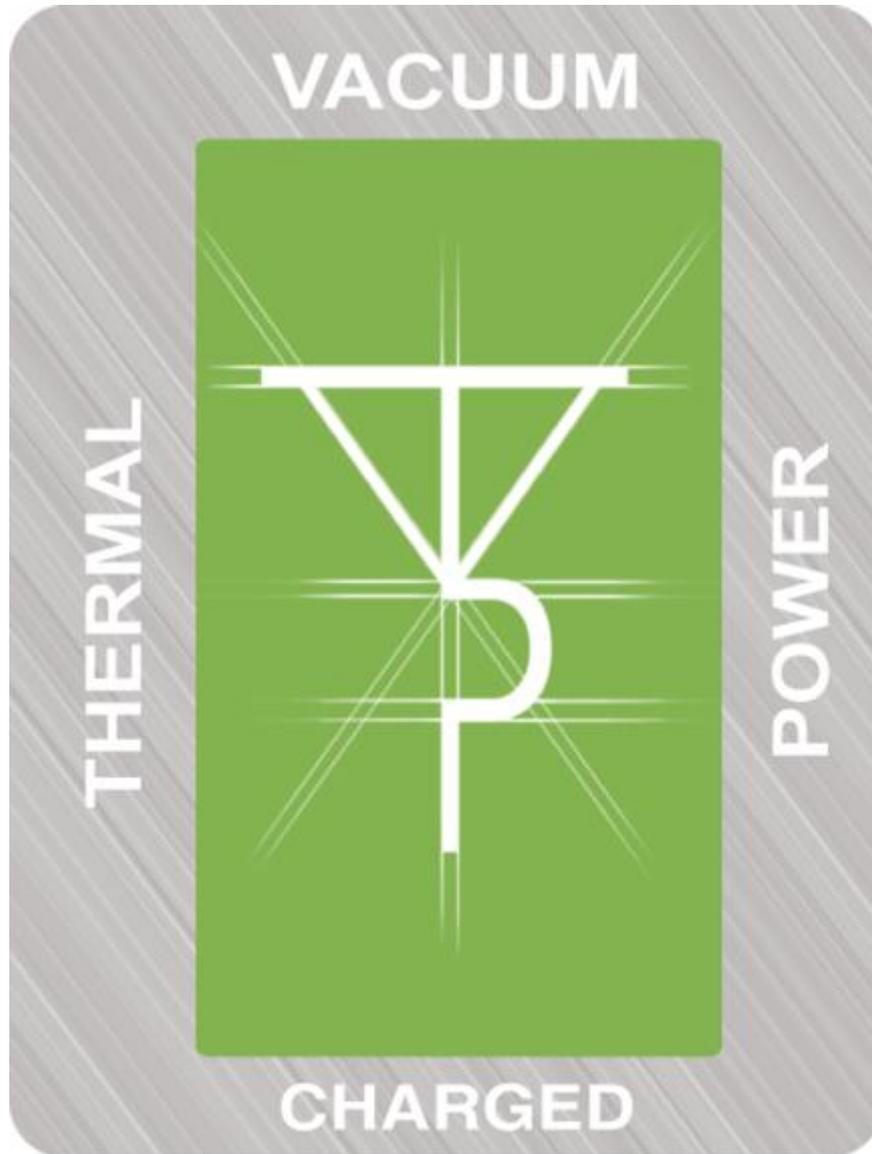
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## Conclusions

- Solar Cooling WORKS!!
- Solar energy by TVP consistently operates absorption chillers with predictable savings
  - *in high-irradiance countries, 2E VAM can be driven up to 180 °C*
  - *in low-irradiance countries, 1E VAM can be driven up to 95 °C*
- SAC by TVP operates in harsh environments (dirt, dust, pollution), without precision cleaning
- Implementing the patented return flow under high vacuum makes the solar field easy to install and maintain, even when using pressurized fluids (up to 14 bar)

## Key Take-Aways

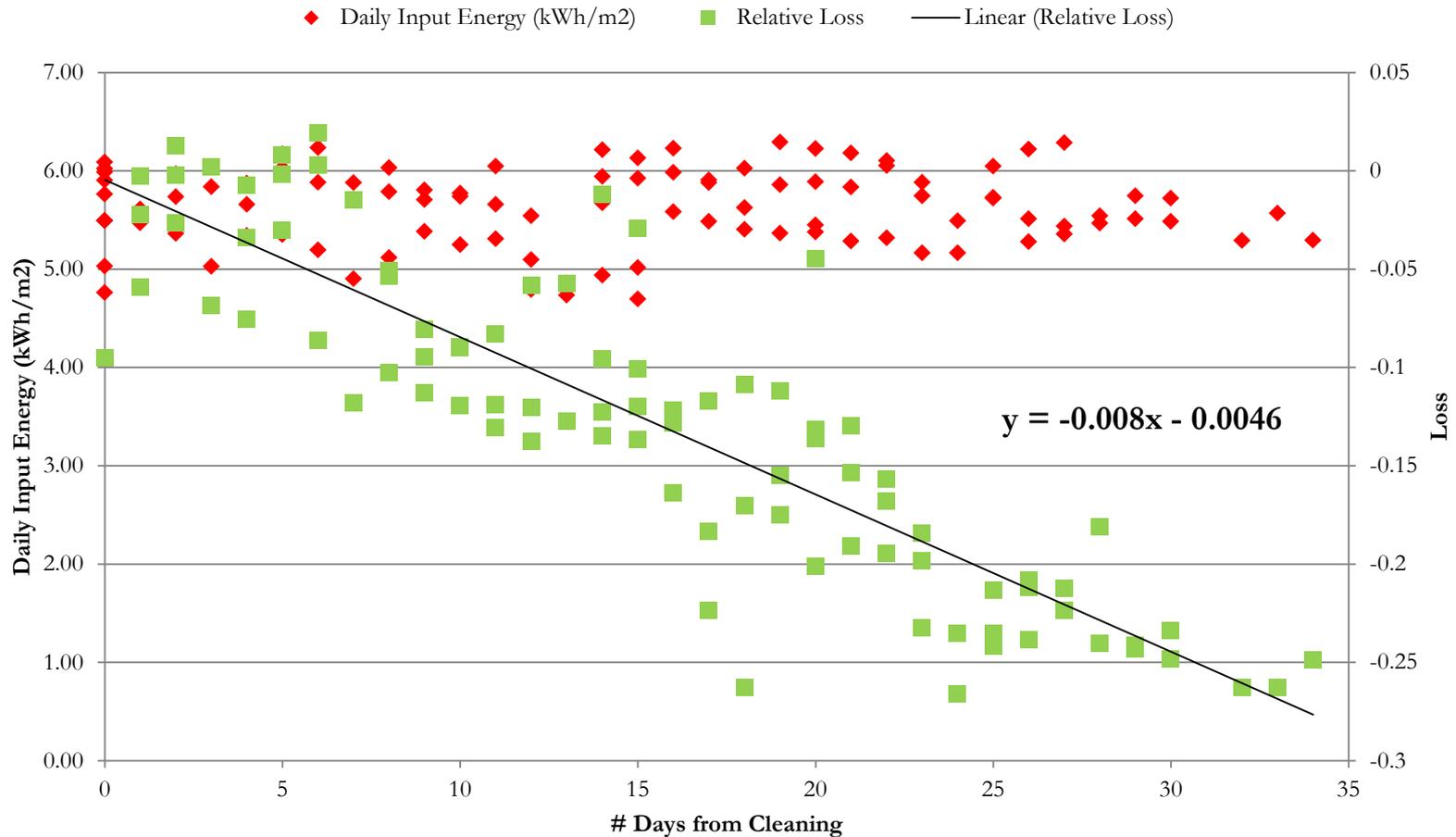
- Designed to operate at high temperature (up to 200 °C) without concentrating mirrors
- Certified best performance up to 200C
- It can work in China, ready to demonstrate it!



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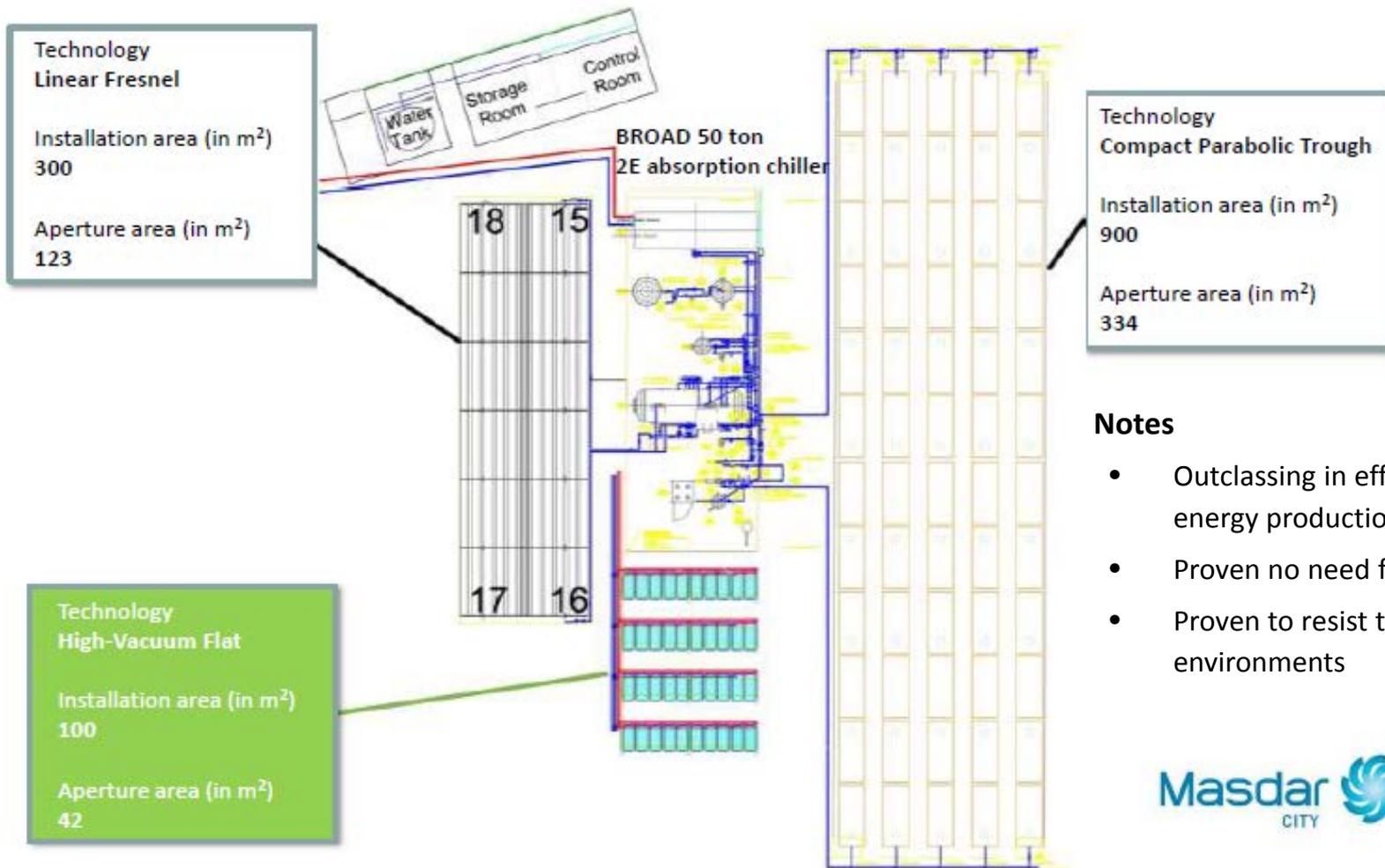
# Effect of Dust Accumulation

## Array Performance



# Masdar City: 180°C in Abu Dhabi, UAE (II)

## Case study 4: direct comparison with Compact Parabolic Trough and Compact Linear Fresnel



# Best Solar Thermal Collector

TVP panels outperforms concentrators (Parabolic Trough or Fresnel) up to 200°C

## Key advantages vs concentrators:

- Highest thermal energy production, mainly due to diffuse light capture
- Highest solar-to-thermal conversion efficiency
- Maintenance-free: no precision cleaning or repair to mechanical parts (no tracking systems)
- Easier transportation, installation and integration
- Long-lasting durability
- Lowest cost profile

