TVP SOLAR

Thermal Vacuum Power

“A new, carbon free thermal energy source replacing fossil fuels”

July 2017

SAINT-GOBAIN NOVAM 2009 ENERGY AWARD WINNER

inter solar award 2012 WINNER

WIPO 2012 AWARD INNOVATIVE ENTERPRISE

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Company Profile: TVP Solar, SA

TVP is a Swiss company, based in Geneva, which designs, develops, manufactures and markets innovative high-vacuum flat solar thermal panels based on patented IP

Mission: to establish high-vacuum solar thermal flat panels as the reference solar technology for industrial and commercial thermal needs, competing with fossil fuels

With headquarters and R&D in Geneva and volume manufacturing in Avellino (Italy), has sales partners covering 15 countries across Africa, Asia, Europe, South America, and the Middle East.

TVP SOLAR

Breakthrough Technology for Solar Thermal

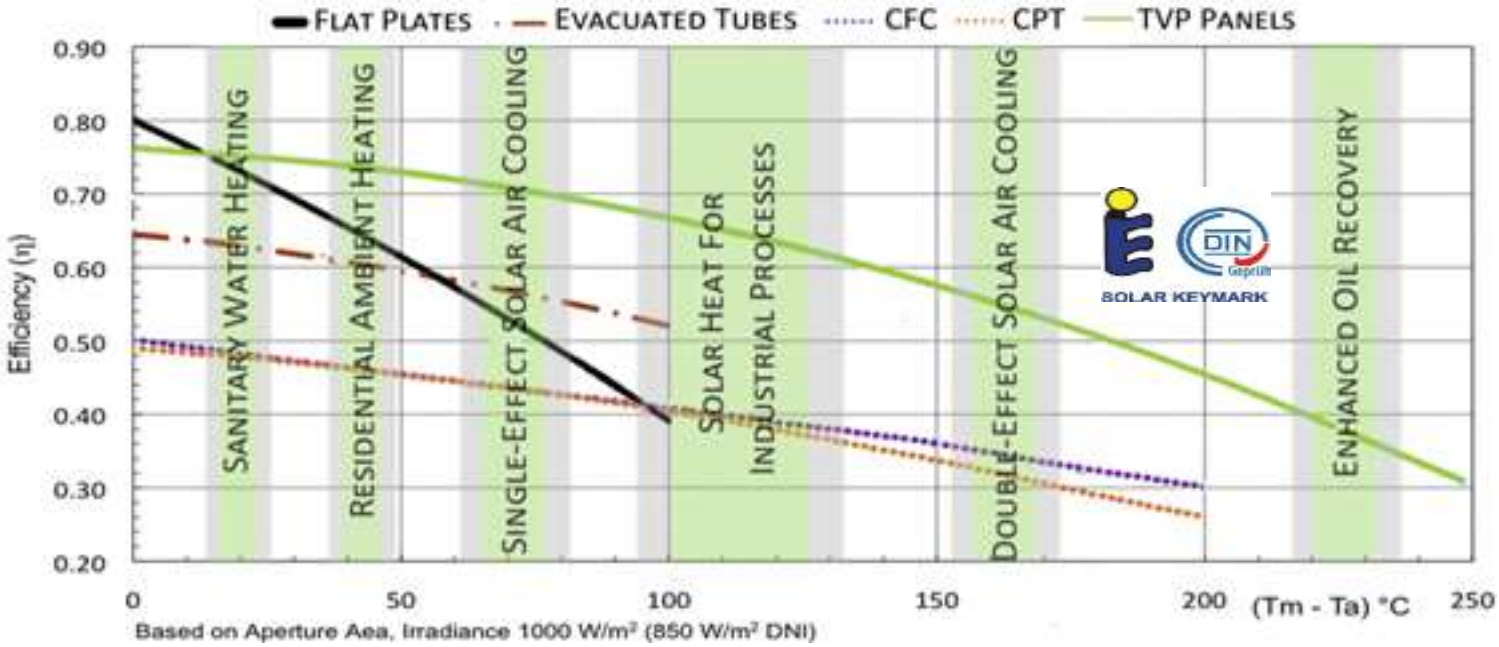
TVP introduces high-vacuum insulation in solar thermal flat plates

High-Vacuum Flat Solar Thermal Panel

- ✓ **Core technology combines high-vacuum insulation with planar layout**
  - ✓ Providing unrivalled performance in any climate conditions:
    high-vacuum completely suppresses convection losses and planar geometry keeps direct flow of thermal exchange fluid entirely under-vacuum
  - ✓ Realizing the cheapest commercially available products:
    same materials as flat plates and high-yield fully-automated mass manufacture process as displays (CRT and PDP)
- ✓ **TVP's technology is based on 10 granted patents**
  - ✓ Core patents refer to new glass-metal sealing technology and self-regenerating non-evaporable getter pump
  - ✓ Other patents cover technology, products and manufacturing process IP

TVP Solar Thermal Collectors: Certified Best Performance

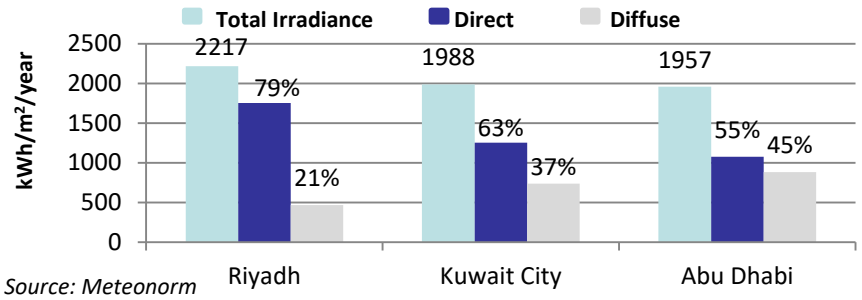
Certified to deliver up to 200°C under SolarKeymark



Highest performance at any operating temperature, any light condition, every thermal application

TVP Unique Feature: No Water-Based Cleaning Required

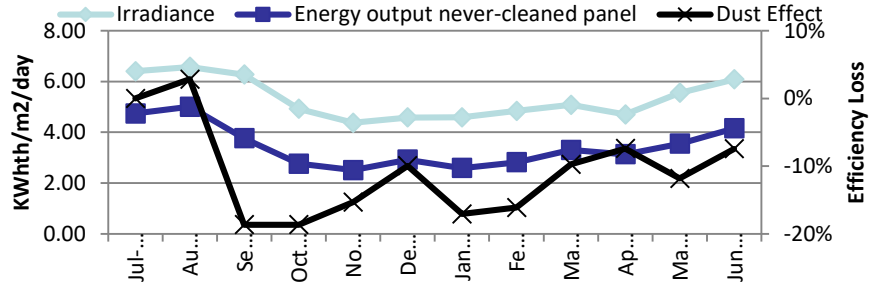
TVP captures both direct and diffuse light



Source: Meteonorm

Dust accumulation increases sunlight scattering (diffuse)

Dust accumulation only affects TVP efficiency up to 20%



Source: TVP, IEA SHC

No cleaning is required by TVP panels

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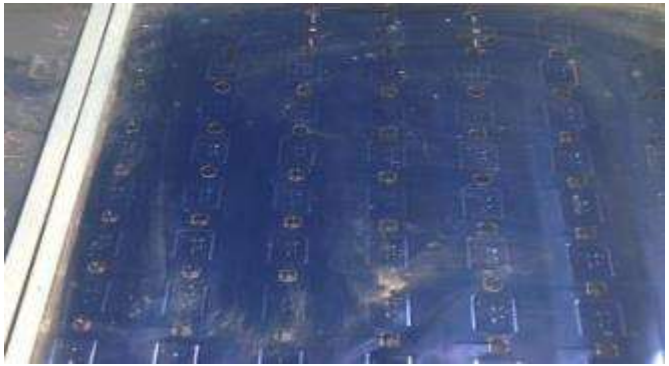
High Performance Even Without Cleaning

Dust accumulation was measured to have minimal effect on TVP performance

May 12th 2015
before cleaning
2,44kWh$_{th}$ with 5.95 kWh$_{th}$ (40% efficiency @175°C)
Peak panel operating temperature 164°C
Peak ambient temperature 43.6°C



May 13th 2015
after dry-brush cleaning
2,73kWh$_{th}$ with 5.71 kWh$_{th}$ (47% efficiency @175°C)
Peak panel operating temperature 176°C
Peak ambient temperature 47.5°C

Dust-covered panel performance only affected by 14%

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The Best Solar Thermal Collector: MT-Power By TVP

TVP panels outperform concentrators (Parabolic Trough or Fresnel) up to 180°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

TVP Solar Thermal Collector: Key Advantages

- ✓ **TVP panels are designed to operate at high temperature**
  - MT-Power panels deliver (up to 200°C) without concentrators or mirrors
- ✓ **Captures diffuse light making panels ideal for polluted, humid, dusty & hazy environments**
  - Takes advantage of up to 40% more sunlight than other technologies!
- ✓ **Totally off-grid thermal supply (removes power demand from the electrical grid)**
  - Peak performance highly correlated with peak demand
- ✓ **Minimal or no cleaning and maintenance**
  - Due capture of diffuse light, panel cleaning is not necessary and can be done at customer option
  - Solar field runs automatically and independently, with a web-based remote control system
- ✓ **Efficiently utilizes available space**
  - Requires minimal footprint
  - Easy architectural integration: can be deployed on any walkable rooftop (50kg bearable load)

Solar Thermal Directly Drives Application Machinery

Driving high energy demanding applications requiring > 100°C and large scale solar fields

Solar air cooling

Absorption chillers
2E @ 180°C
1E @ 95°C

Solar process heating

Industrial boilers up to 180°C

Solar oil processing

GOSPs and others up to 180°C

Solar desalination

MED/TVC, MED &MSF 80°C to 180°C

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Solar Heat For Industrial Process Heat (SHIP) Applications

Solar thermal directly drives heat-intensive applications through 200°C + pre-heating

Boilers

Steam Machines

Drying Machines

Solar thermal panel design:

Mirrorless, flat geometry
with high-vacuum insulation

Panel features:

Corrosion-proof all-metal casing
Embedded return HTF flow under high-vacuum
Spot-Check™ visual vacuum verification
100% recyclable

TVP target industries include:

Pharmaceuticals	Chemical
Textiles	Pulp & Paper
Food & Beverage	Hospitals
Oil & Gas	Industrial Laundry

TVP directly serves applications:

Thermal fluid up to 180°C, 14 bar directly or via heat exchanger, minimizing electricity or combustible consumption. Supports steam applications via ISG.

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TVP SHIP: System Strengths & Uniqueness

Game-changing value proposition for industrial processes with TVP panels

Minimizes fossil fuel consumption

Substitutes & cuts diesel and other fossil fuels burned, running thermal process via solar with combustible auxiliary. Highly relevant to regions with limited distribution networks and remote locations with associated high cost and scarcity of fuels

Best solar solution for dusty, hazy, polluted, humid & overcast environments

Any solar field output is affected by light conditions and further reduced by particulate accumulation on collector surfaces. Uniquely, TVP panels require no water-based cleaning in these environments, because high vacuum insulation enables effective capture of full-spectrum diffuse light.

Scalable in terms of capacity and solar contribution

TVP-based solar field modularity and scalability in thermal demand meets both heat and energy needs of any client. Solar contribution to energy requirements uniquely can be further scaled and extended over daylight operations via thermal storage.

Flexible to match any client need in any weather condition

Boiler/steam generator hybridization via an integrated auxiliary burner allows maximum solar use in any weather condition. SHIP can be configured to serve new machinery and integrated into existing systems mainly via heat exchanger.

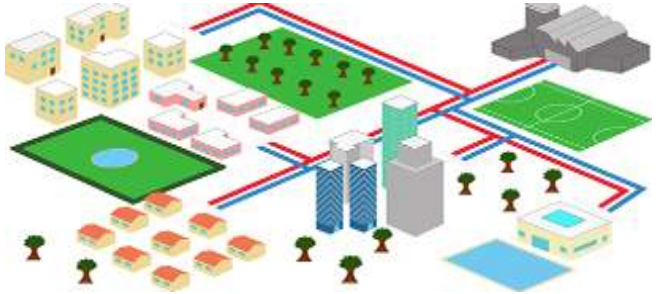
Significantly reduce CO_2 emissions

TVP replaces diesel and fossil fuels directly, immediately reducing carbon dioxide and other pollutant emissions. SHIP thus not only reduces operating costs but also allows adopters to achieve sustainability goals, both corporate and international.

Solar-Assisted Industrial Process Heat

SAC integrates w/ central air conditioning units/ducts, for existing and new-build facilities

District Heat



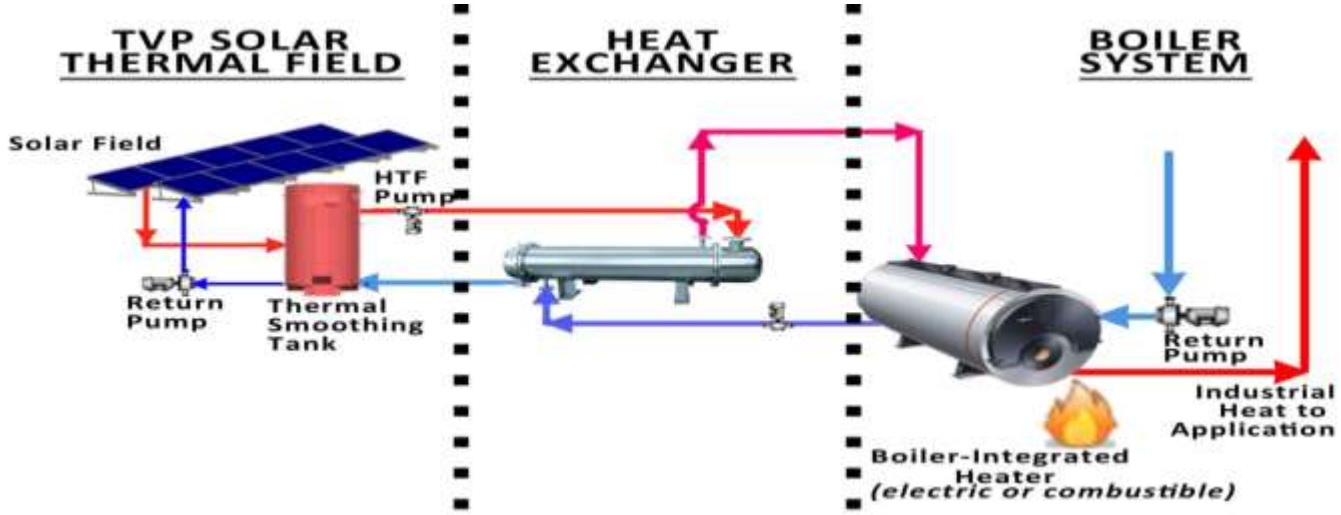
Steam Boiler Feedwater Heating

Food & Beverage Kilning

Sterilizers & Autoclaves

TVP SHIP: Indirect Boiler Heating For Large Capacities

Solar-only SHIP model – typically for pre-heating or heating, integrating with existing



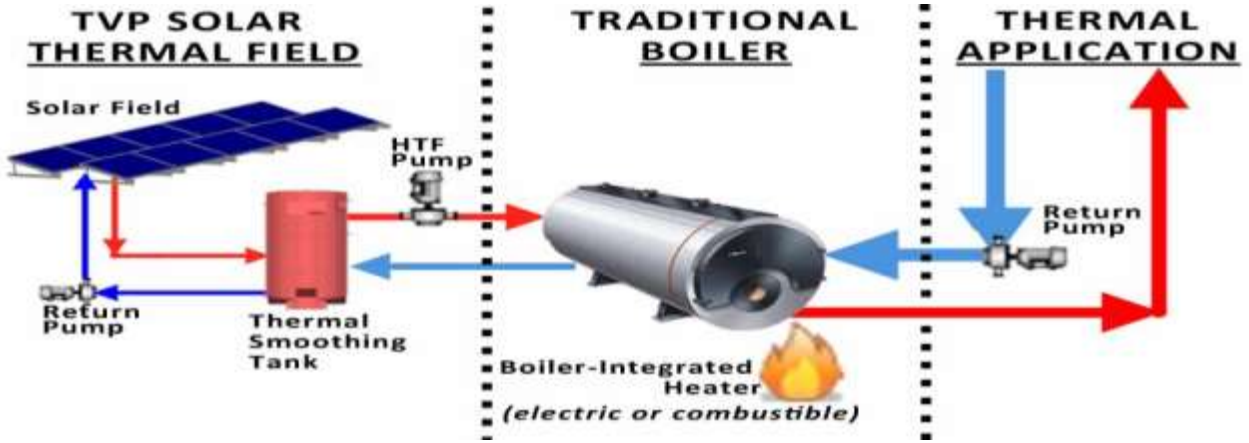
Electricity or combustible consumption is minimized by the addition of a solar field sending hot fluid (pressurized water or diathermic oil) to a heat exchanger and serving a boiler with integrated heater (resistance or burner).

This configuration significantly reduces traditional energy needs by replacing burner or heating element during daylight hours. The solar field acts both as a replacement and as pre-heating booster when sunlight is insufficient.

Solar thermal contribution to thermal requirements depends on solar field size.

TVP SHIP: Direct Boiler Heating For Large Capacity

Solar-only SHIP model – typically for pre-heating or heating



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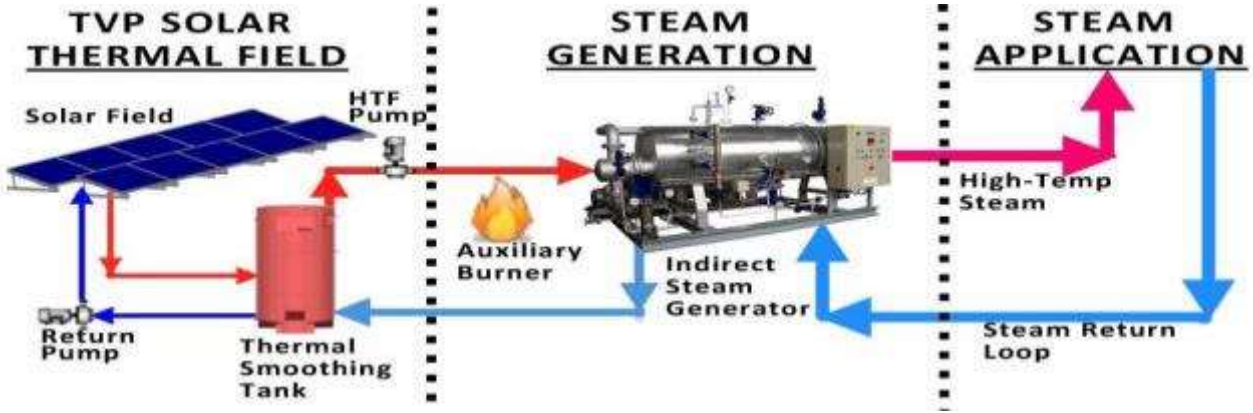
This configuration significantly reduces traditional energy needs by replacing burner or heating element during daylight hours. The solar field acts both as a replacement and as pre-heating booster when sunlight is insufficient. TVP does not suggest this config as it does not insulate field from process.

Solar thermal contribution to thermal requirements depends on solar field size.

TVP SHIP: Steam Generation Up To 150 psi

Solar + combustible hybrid model via indirect steam generator (ISG)



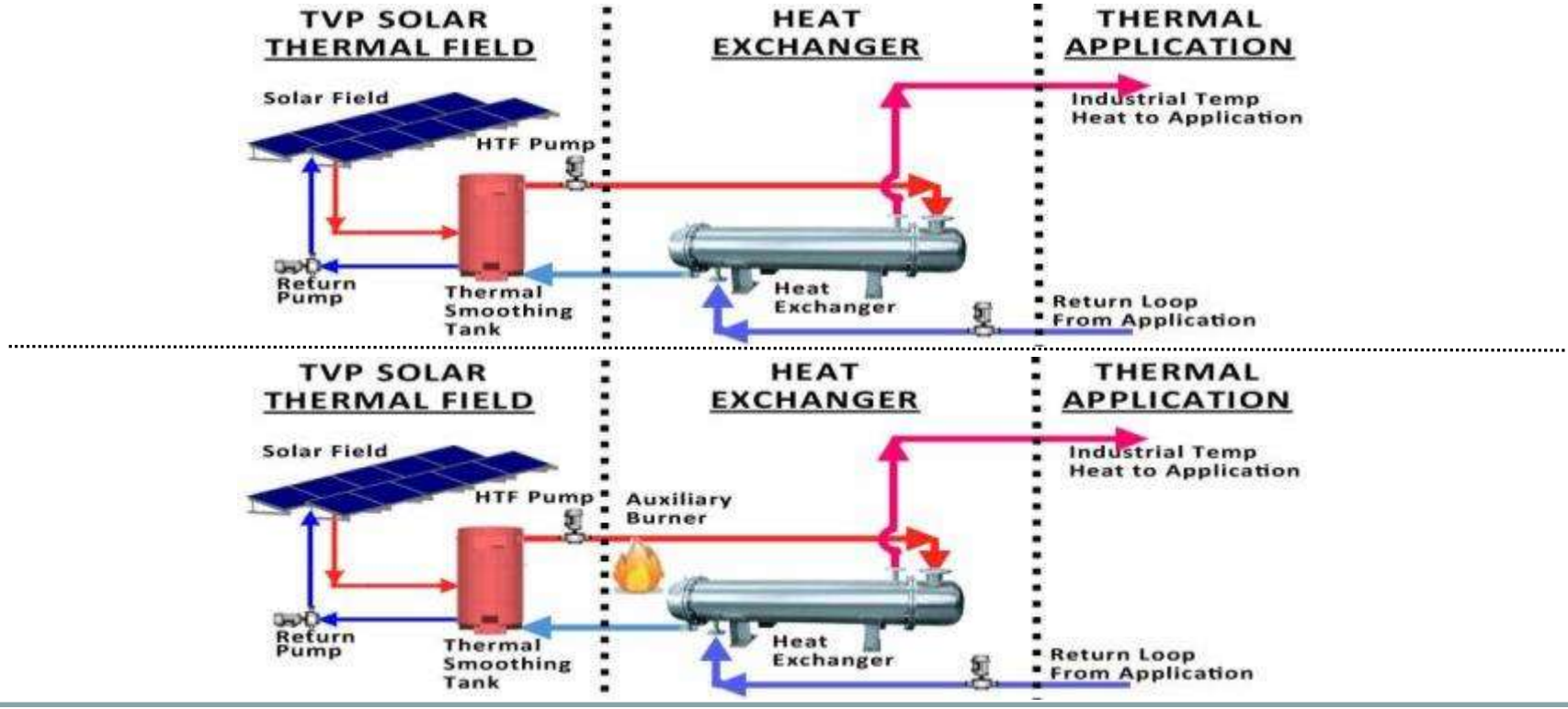
Solar energy complemented by a natural gas, LPG, diesel, biogas or biomass burner, provides steam up to 24/7 at required pressure via an indirect steam generator. The burner provides additional lift between solar field thermal generation and temperature required by an indirect steam generator.

This configuration maximizes the use of solar energy, because the steam generator takes advantage of any temperature generated by the solar field during daylight hours.

Solar thermal contribution to SHIP requirements depends on solar field size and related thermal storage capacity (which can extend solar use over daylight hours).

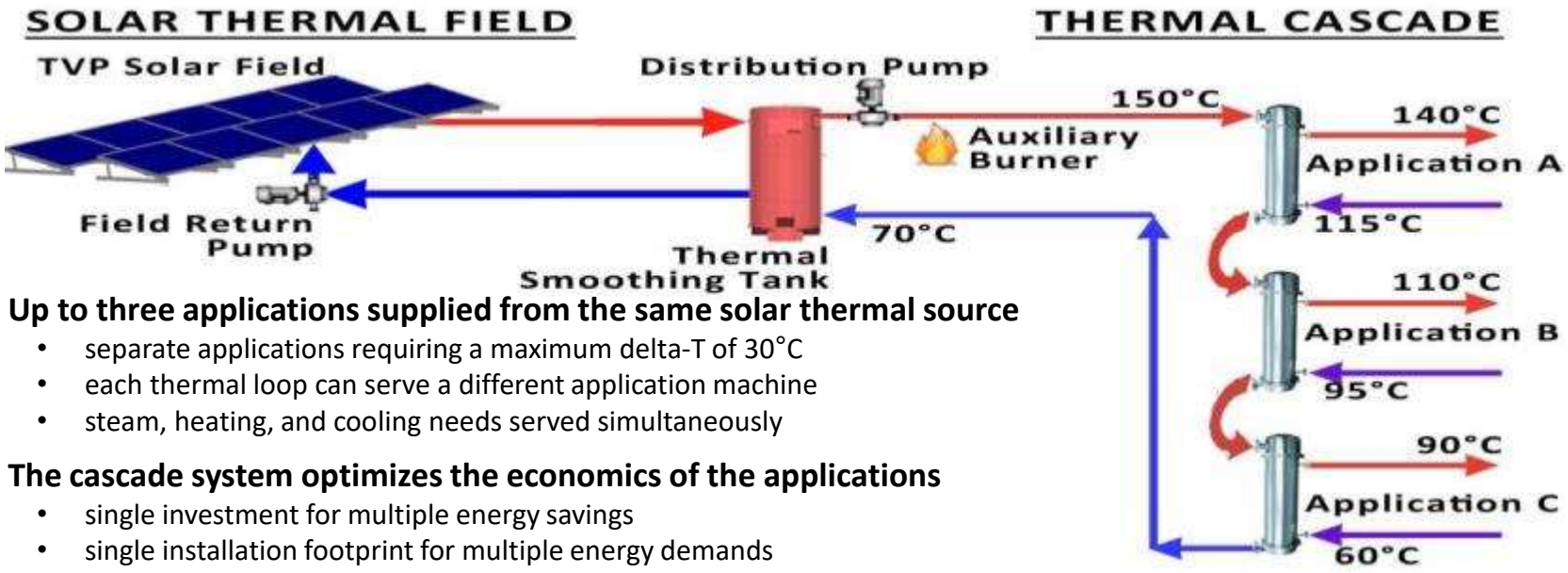
TVP SHIP: Serving Heat Exchangers

Solar-only or hybrid mode to heat or pre-heat application fluids



TVP SHIP: Cascade Configuration For Multiple Needs

One field, multiple heat services



- **Up to three applications supplied from the same solar thermal source**
  - separate applications requiring a maximum delta-T of 30°C
  - each thermal loop can serve a different application machine
  - steam, heating, and cooling needs served simultaneously
- **The cascade system optimizes the economics of the applications**
  - single investment for multiple energy savings
  - single installation footprint for multiple energy demands
- **One solar field provides thermal energy above the highest required temperature**
  - each application is a separate, closed loop to ensure system integrity
  - optional combustible burner for 24/7 operation and/or constant temperature supply

TVP Solar-Driven Industrial Process Value Proposition

- ✓ **Proven breakthrough panel performance**
  - reliable energy output and no need for cleaning
  - installed and operational in KSA , UAE and Kuwait since 2012
- ✓ **Save fossil fuel and cut CO_2 emissions**
  - particularly effective during peak demand hours during daytime
  - solar thermal energy can be distributed at any time via storage
  - invest in the only source of energy which can provide payback on system CAPEX
- ✓ **Solar field integrated as add-on, contributing energy without affecting existing operations**
- ✓ **Stabilize energy bills over 20 years and industrial cost of client products**
  - highly volatile energy market prices are offset with stable energy output from solar field
- ✓ **Minimize dependence on electricity (in particular at peak hours) and diesel supply**

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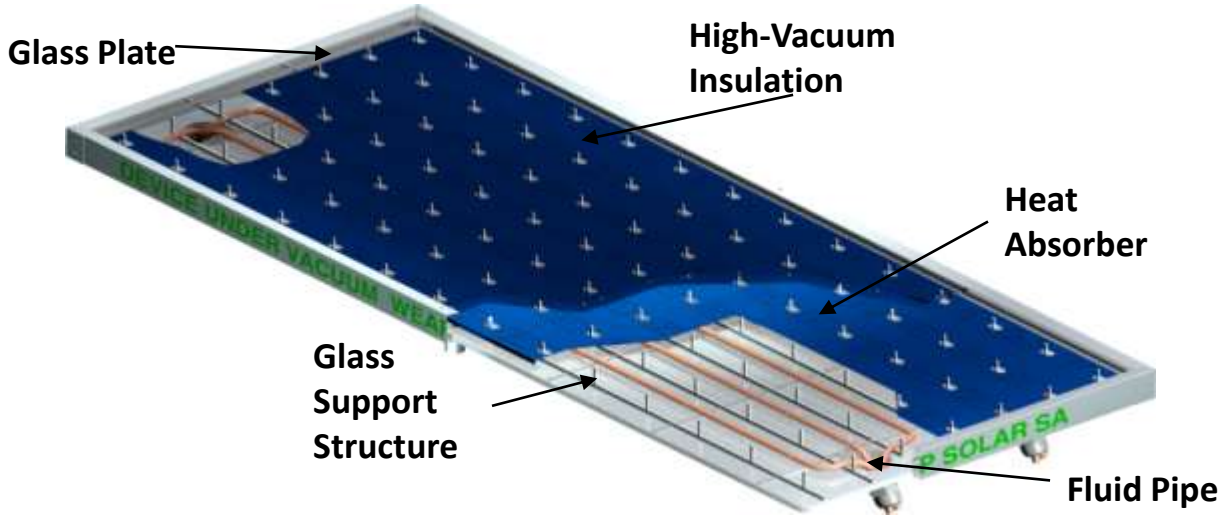
Thermal Vacuum Power Charged™ Products

Flat geometry outside to maximize sunlight capture and vacuum inside to maximize heat retention

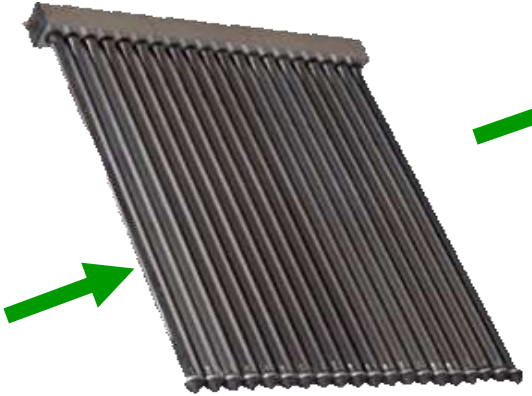


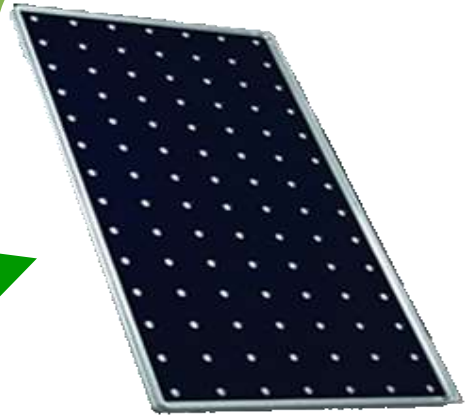
TVP panels capture all available sunlight: both direct and diffuse light for best thermal energy output

TVP: The Ultimate Solar Thermal Panel

1st Gen:
Planar Layout

2nd Gen:
Vacuum Insulation





3rd Gen:
Planar Layout
+
Vacuum Insulation

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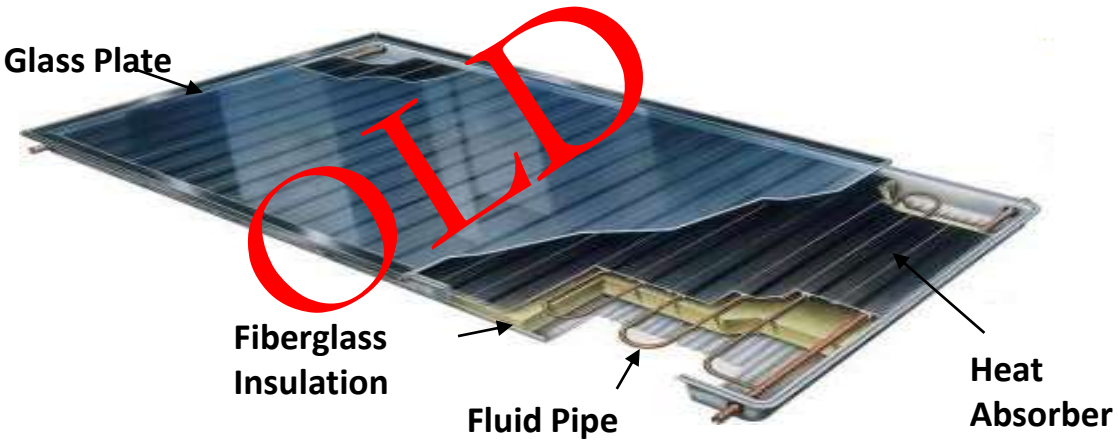
TVP: Evolving From Flat Plates

Taking the best specs: robustness and ratio of aperture/gross area

Flat plates are considered the simplest and cheapest form of glazed solar collectors

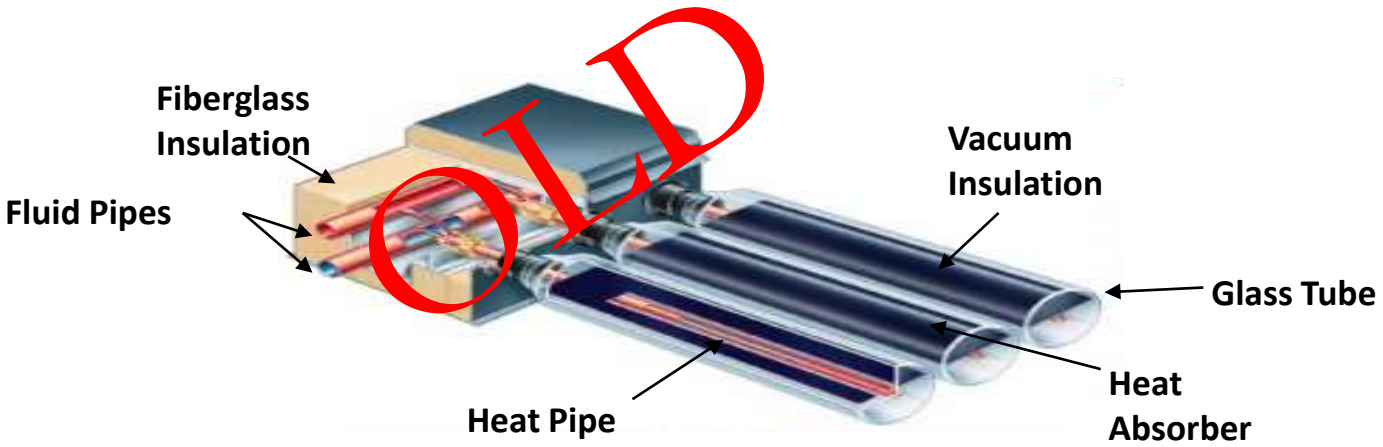


Efficiency is severely limited by heat losses due to internal convection since thermal insulation is normally placed only at the back side

TVP: Evolving From Evacuated Tubes

Taking the best specs: high-vacuum insulation

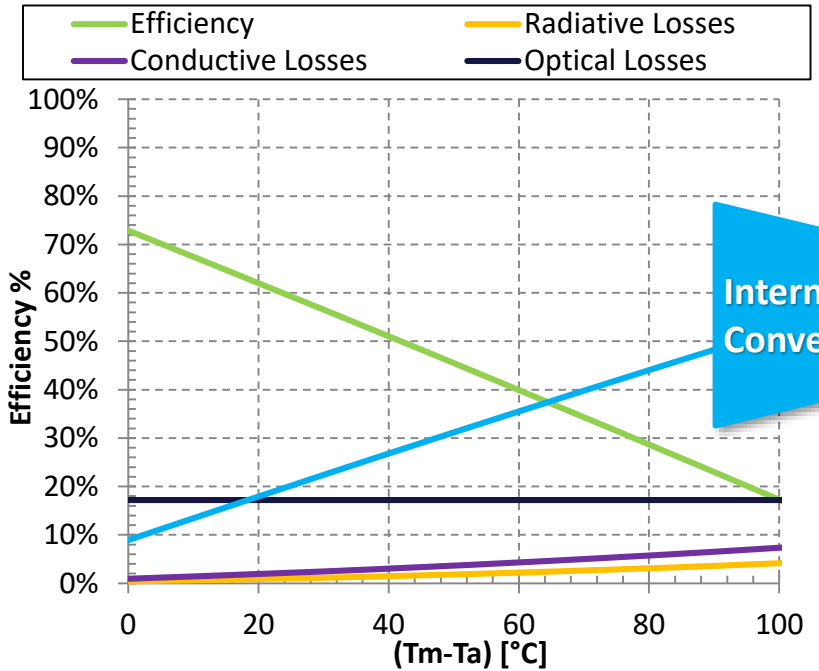
Until now, evacuated tubes were considered the best non-concentrating collectors available. They offer the best compromise to make use of vacuum insulation, as tubular topology easily sustains the high mechanical stress of vacuum.



Evacuated tube efficiency is limited by the presence of several heat flow barriers (in particular for Sidney type collectors) and manifold insulation

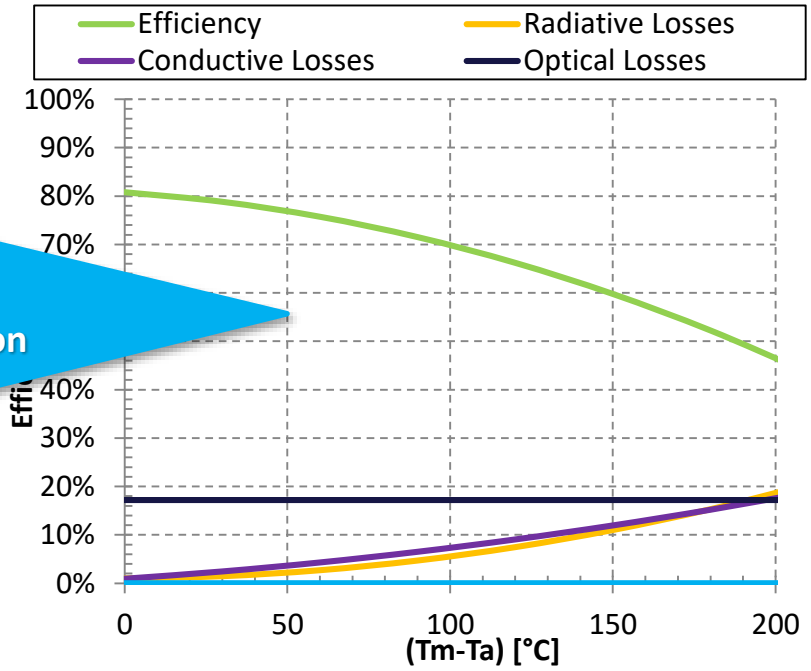
High-Vacuum Delivers Best Thermal Performance

High-vacuum is a perfect insulator, completely suppressing convection losses



Traditional fiberglass insulation

Internal Convection



High-vacuum insulation

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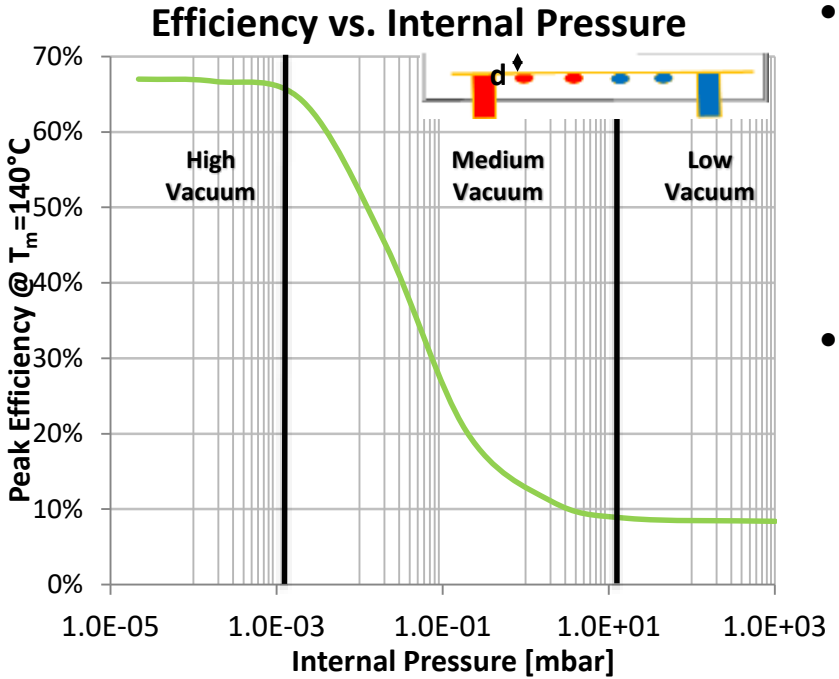
High-Vacuum: Internal Pressure < 10^{-3} mbar

Only high-vacuum completely suppresses convection losses

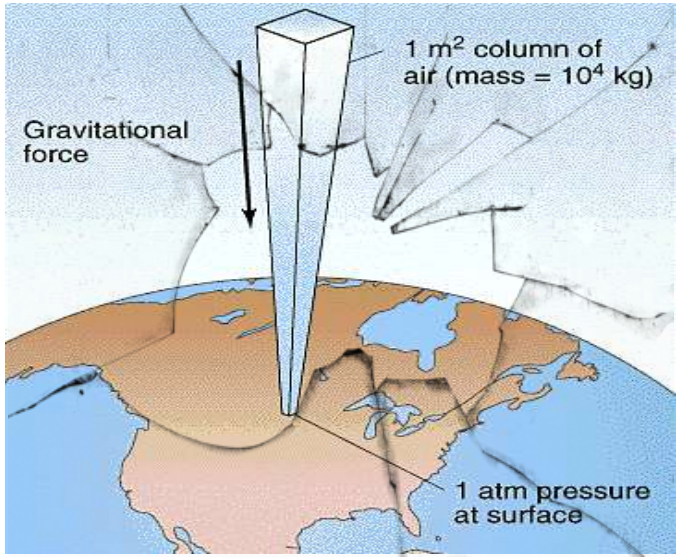


- Reducing internal pressure in a solar panel envelope only slightly reduces convection until the mean-free-path of residual gas molecules gets longer than the gap between the absorber and the envelope (d)

- Under such conditions (typically reached at 10^{-1} mbar for d=1 cm) molecules collide with the walls more often than with each other and gas heat conductivity becomes proportional to pressure and surface area only (not to gap width), disappearing below 10^{-3} mbar (high-vacuum)

TVP Has Overcome Major Vacuum-Related Challenges

Making and maintaining vacuum in a flat box are historically the major hurdles

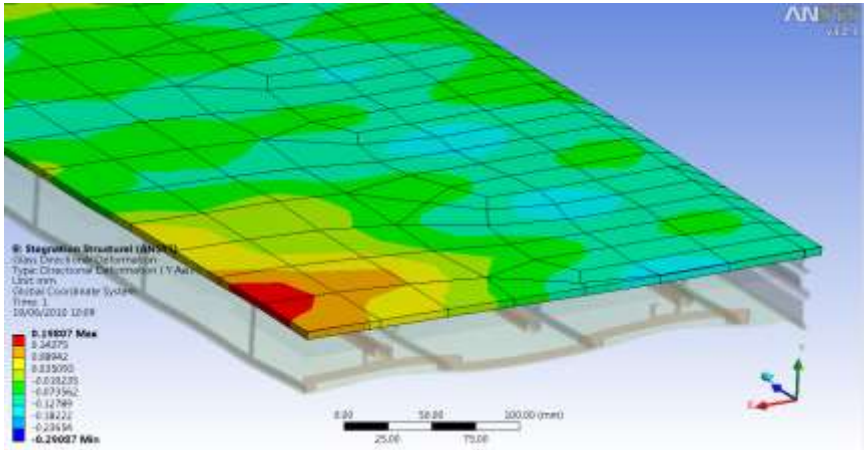


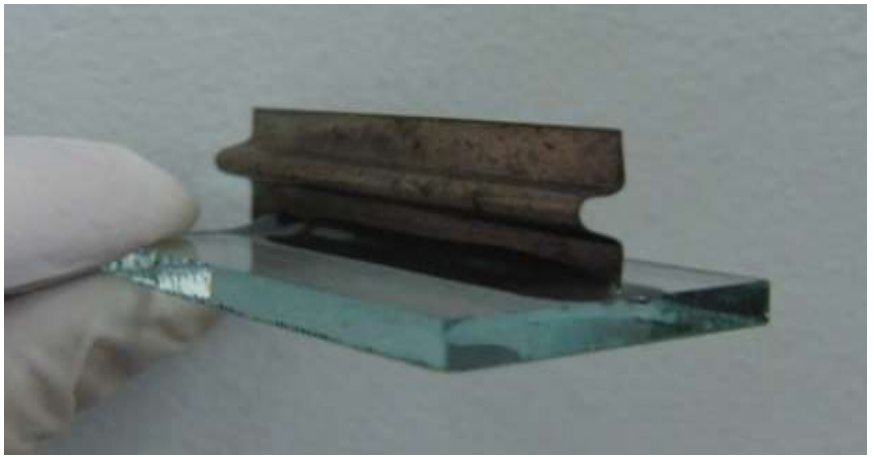
Supporting glass plate against atmospheric pressure (10 ton/m^2)

Providing long-lasting (20 years) high-vacuum (< 10^{-3} mbar) inside panel

Making Vacuum: Patented Glass-Metal Seal Technology

The Only Seal to Allow High Vacuum Conditioning for Flat Plates



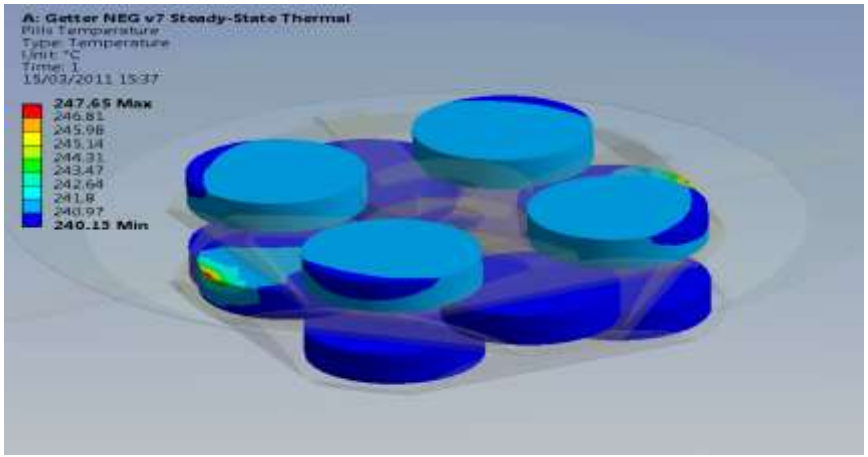


A patented fully inorganic and flexible glass-metal seal

- ✓ Adds mechanical reinforcement to chemical bonding process
- ✓ Allows high vacuum up to 10^{-9} mbar
- ✓ Resistant to high-temperature vacuum conditioning up to 270°C
- ✓ Made with standard materials qualified for long lasting vacuum

Maintaining Vacuum: Patented Getter Technology

Self-Regenerating Getter to Allow Long Lasting High Vacuum



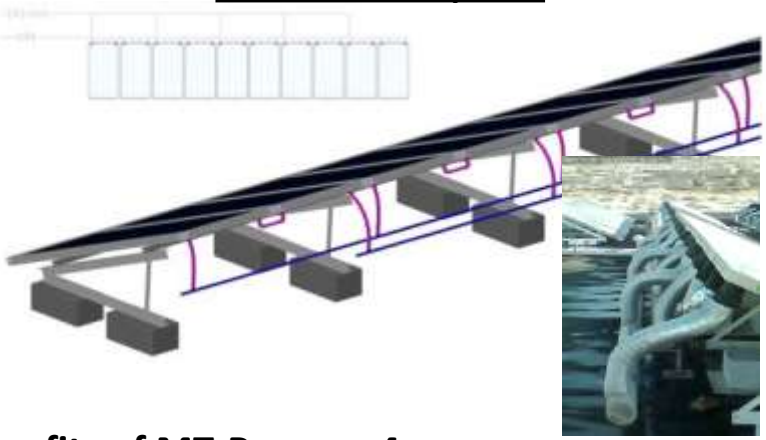
A patented non-evaporative getter pump capsule

- ✓ Ensures high vacuum integrity for over 20 years
- ✓ Self regenerates standard NEG pills with solar energy
- ✓ Automatically activated during vacuum exhaust process

Extending Vacuum Benefits: Patented Heat Absorber

Optimizing insulation of return flow by maintaining within vacuum envelope

Traditional flat plates



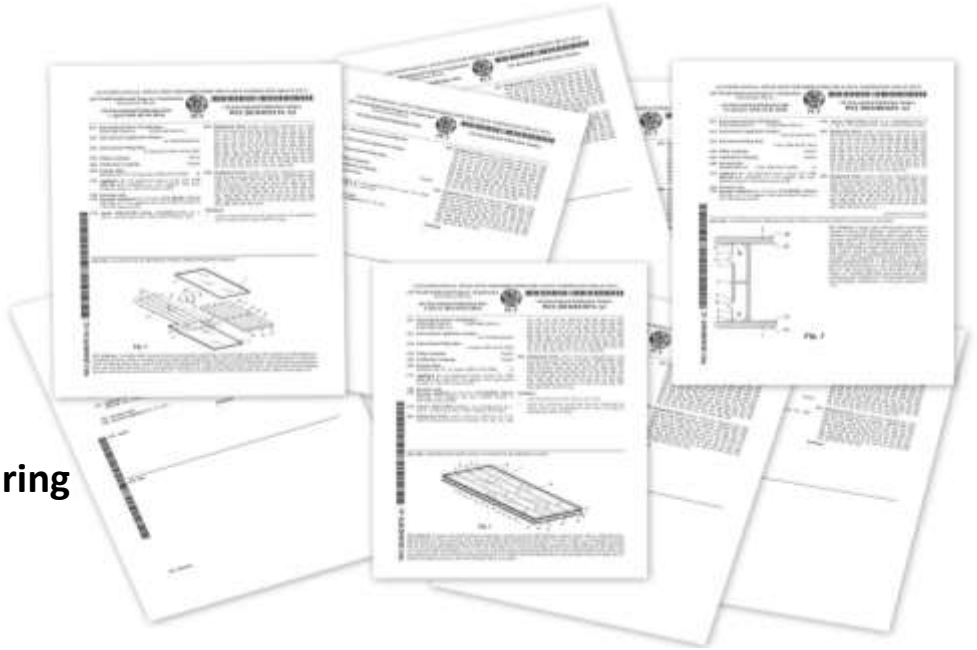
TVP

Benefits of MT-Power v.4 :

- ✓ 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 Intellectual Property: Proprietary & Patented

TVP Solar owns 10 patent families protecting breakthrough core technology, products and manufacturing



Thermal Vacuum Power Charged™ technology is a collection of several inventions, related to both panel components and manufacturing processes, patented worldwide

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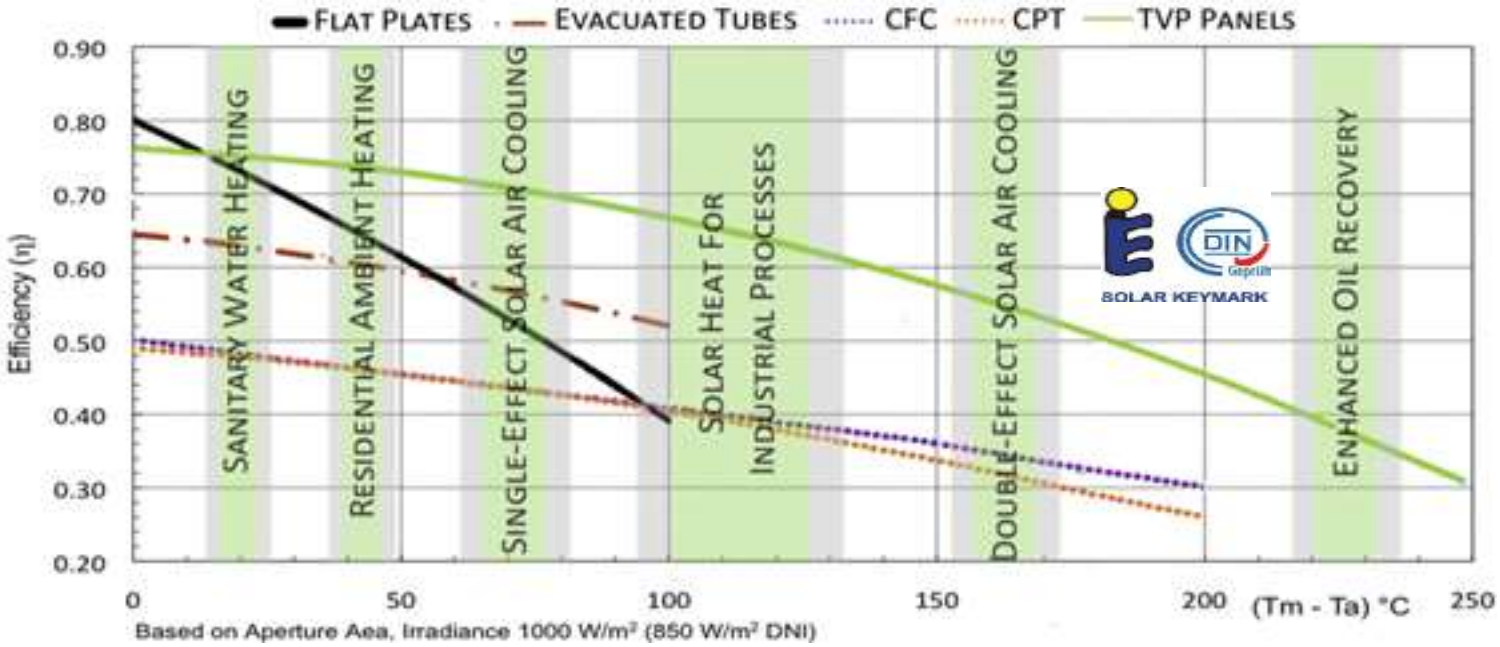
TVP Solar Thermal Collectors: Certified Best Performance

Certified to deliver up to 200°C under SolarKeymark



Highest performance at any operating temperature, any light condition, every thermal application

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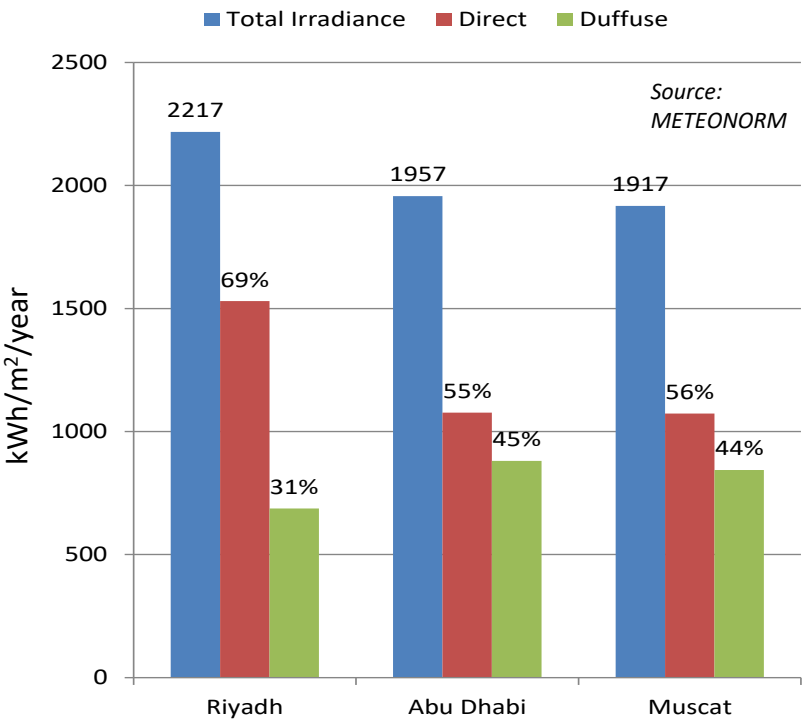
Main Differentiating Factor: Diffuse Light Capture

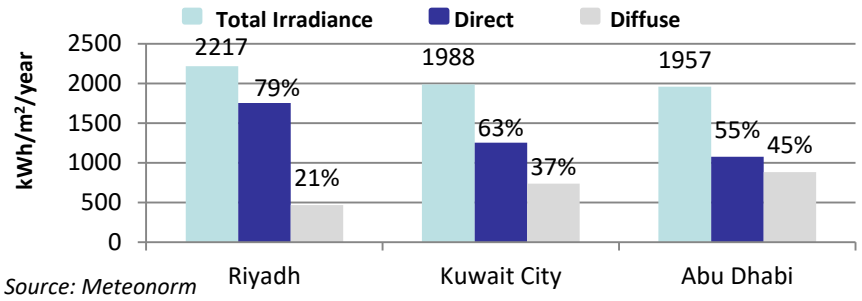
Clouds, humidity, dust, pollution, and sand contribute heavily to diffuse light



- 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

TVP Unique Feature: No Water-Based Cleaning Required

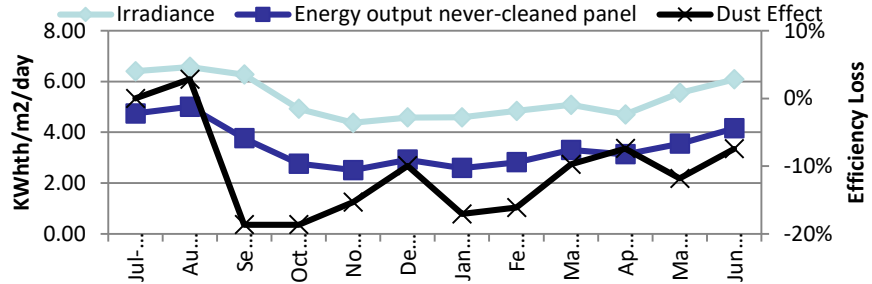
TVP captures both direct and diffuse light



Source: Meteonorm

Dust accumulation increases sunlight scattering (diffuse)

Dust accumulation only affects TVP efficiency up to 20%



Source: TVP, IEA SHC

No cleaning is required by TVP panels

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Consistent and Predictable Energy Output

Simulation results verified by field tests and deployments

Solar radiation on horizontal surface		Tout (°C)									
		60	95	110	120	130	140	150	165	180	190
2217	kWh/m^2/year	1727	1528	1427	1355	1279	1200	1118	1034	861	773
2117	kWh/m^2/year	1702	1502	1401	1330	1255	1179	1099	977	852	768
1988	kWh/m^2/year	1557	1363	1266	1297	1125	1050	974	857	738	659
1957	kWh/m^2/year	1528	1333	1234	1163	1090	1013	935	814	691	609
1839	kWh/m^2/year	1391	1200	1104	1034	966	895	822	712	602	530
1755	kWh/m^2/year	1384	1184	1086	1017	947	875	802	692	583	511
1638	kWh/m^2/year	1281	1081	983	916	847	776	706	600	496	428
1529	kWh/m^2/year	1187	992	900	836	772	706	641	544	449	389
1444	kWh/m^2/year	1128	932	839	775	710	644	579	484	393	335
1325	kWh/m^2/year	1018	831	745	686	627	569	511	427	347	296
1208	kWh/m^2/year	884	706	627	573	520	468	417	343	273	230
1112	kWh/m^2/year	811	637	559	508	457	407	359	290	228	190
		MT-Power Energy Production									

The Best Solar Thermal Collector: MT-Power By TVP

TVP panels outperform concentrators (Parabolic Trough or Fresnel) up to 180°C

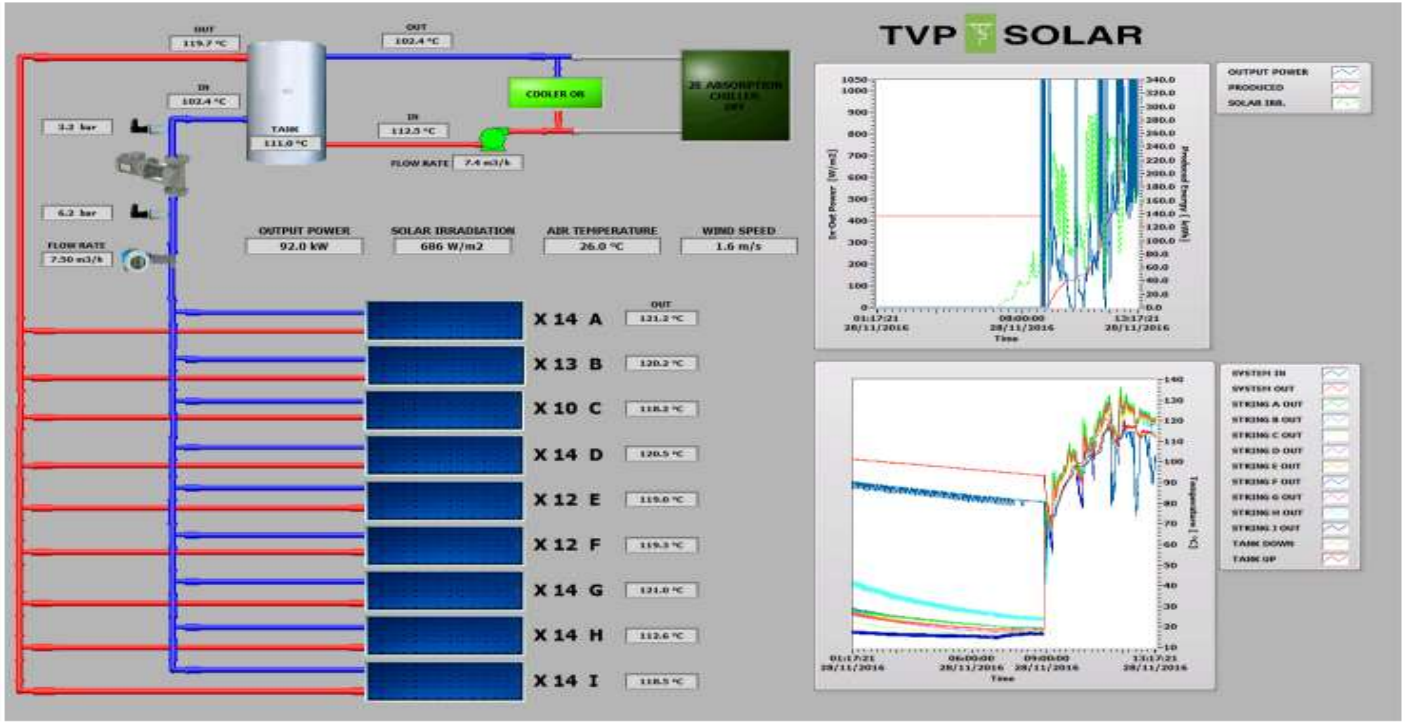
Key advantages vs concentrators:

- 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

TVP SOLAR

Real-Time Data Monitoring

Proprietary hardware + software platform for local and Web-based remote access



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What Can TVP Do For You?

- ✓ **Thermal energy supplied by a TVP solar system is not affected by any variance in market energy prices; it's based on sunlight.**
- ✓ **The cost of energy is relative to solar field investment, and is identical in economic impact as an energy pre-payment.**
- ✓ **This means that the end-user is insulated from changes in yearly energy costs, which tend to increase over time. This is expressed in the levelised cost of cooling.**

TVP SHIP System: Replacing LNG For Process Heat

Solar field replaces 95% of daily demand thermal energy to make steam

SHIP Process: Energetics via Solar	Replacing LNG
# of Panels	396
Solar Panel Gross Area (m^2)	792
Solar Field Area Requirement (m^2)	1,426
Total Heat Energy Requirements (kWh_{th}/year)	837,103
Thermal Energy Covered by Solar (kWh_{th}/year)	**786,869**
Remainder Energy Covered by Existing Boiler (kWh_{th}/year)	50,234
Solar Contribution to Total Heat Energy (%)	**94.00%**
Thermal Energy Produced by Solar (kWh_{th}/year)	825,435
Heat Exchanger Efficiency (%)	95%
Hours of Solar Contribution (hrs/day)	7.9
Hours of Full Load Coverage By Solar Field (hr/day)	4.9

✓ **SHIP displaces need for LNG**

- solar field supplies heat for steam generator
- solar field runs 8 hrs per day @ 110°C
- 5 hours per day no LNG is burned
- 95% of yearly LNG need is replaced

✓ **Client yearly OPEX is slashed**

- solar reduces operating costs by replacing a variable cost base
- once solar field payback is reached OPEX in daytime hours is near-zero

✓ **Cost of energy stabilized**

- solar system yearly output is predictable and constant
- LNG prices are currently rising

Contact Us For More Information & Solution Feasibility

TVP will supply a detailed feasibility study including:

- Preliminary solar field design
- Energetic performance simulation
- Budget quotation
- Economic impact analysis

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