TVP SOLAR

Thermal Vacuum Power from the Sun

Solar Energy Applications

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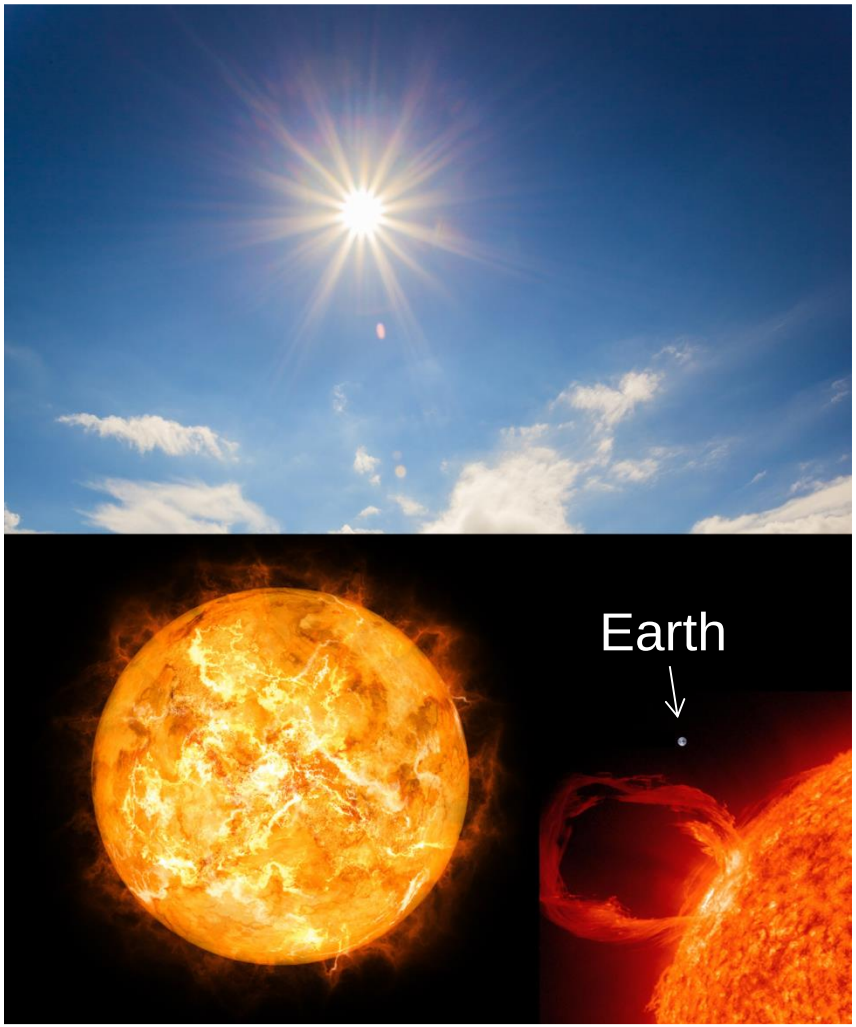
2012 Award for Innovative Enterprises Winner
WIPO World Intellectual Property Organization

inter solar award 2012 WINNER

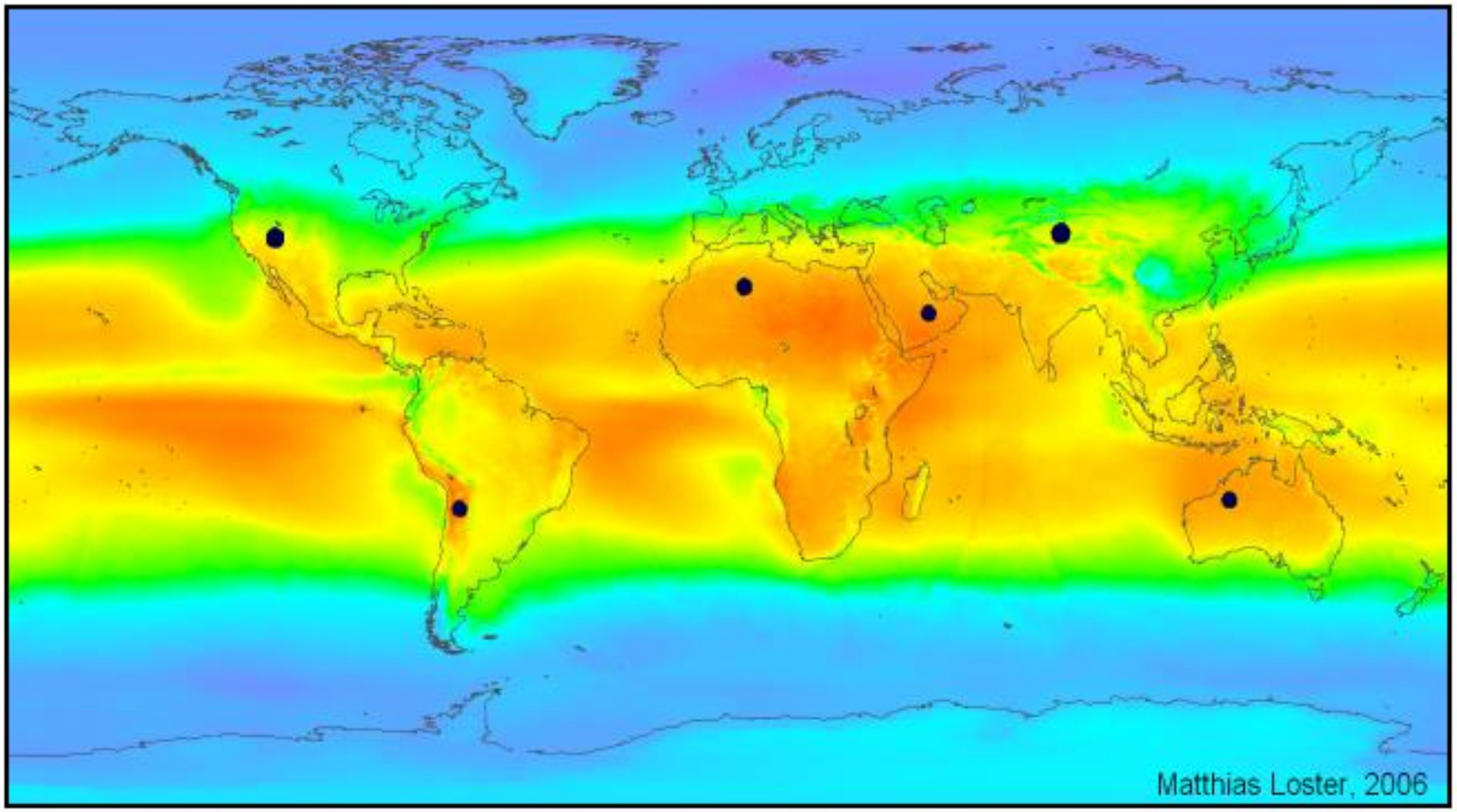
SAINT-GOBAIN NOVAM
2009 ENERGY AWARD WINNER

The Sun

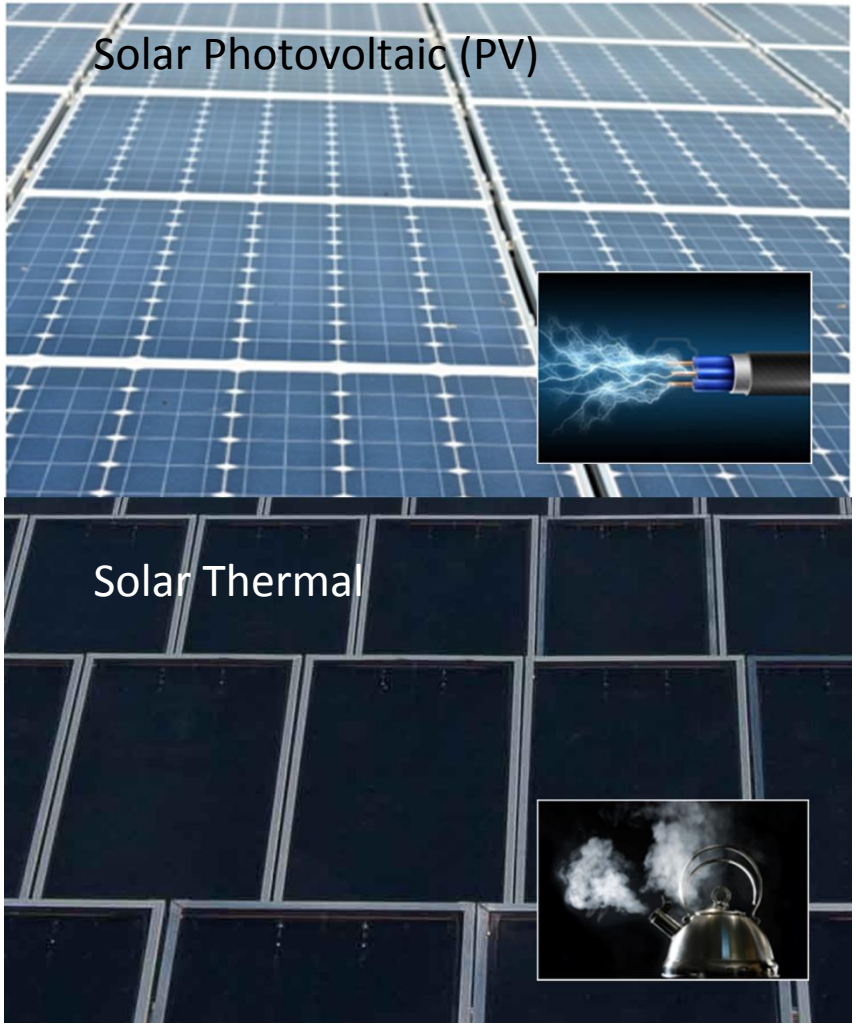


- The Sun is a yellow dwarf star 1.3 billion times larger than planet Earth
- 75% of the Sun is made of Hydrogen that, because of gigantic gravitational force compression, is transformed into Helium via thermonuclear reactions
- Thanks to these reactions, the Sun illuminates Earth with 1.7E+17 W of power or about 5.6E+20 J of energy reach its surface every hour
- This is roughly the amount of energy consumed by humanity in 2002

World map of solar irradiation

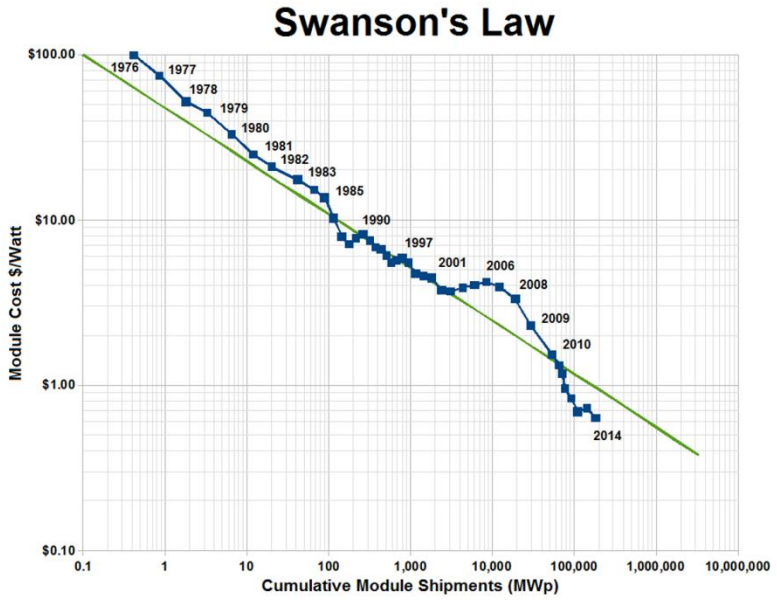


Solar energy harvesting



- Solar energy can be harvested in two different ways:
  - solar photovoltaic panels convert photon energy into electricity via the photoelectric effect, using semiconducting materials (i.e. Si or III-V compounds)
  - solar thermal panels convert photon energy into heat absorbing the Visible part of the e-m spectrum while only partially re-emitting in the IR using low emissivity metals (i.e. Cu or Al)
- In both cases it is not possible to convert the entire amount of photon energy (panel efficiency)

History of PV

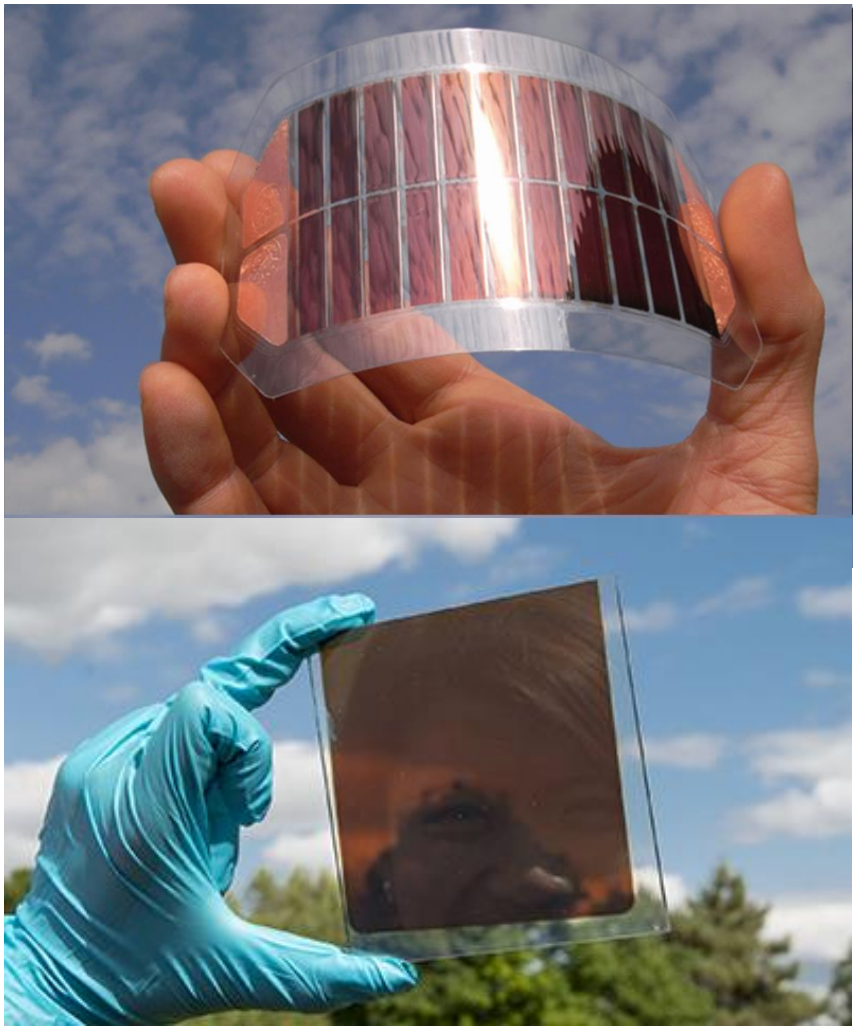


- In 1955 Hoffman Electronics commercialised PV cell with 2% efficiency at a cost of 1500 $/W
- In the ‘60 and ’70 the Space Race favoured a rapid development of PV technology for spacecraft and satellite applications
- In the first two decades of 21st century, a dramatic cost reduction fuelled by rapid capacity growth brought the cost of whole PV modules below 1$/W, with an average 17% efficiency
- Today PV modules are available both with bulk an thin-film cells

PV applications

- Today the majority of PV panels are used for grid connected power generation
- Sizes range from few kW for houses to several hundreds of MW for power plants
- Levelised cost of energy for large scale installations in high irradiation countries (India, Saudi Arabia, Mexico) has fallen below 3 ¢/kWh becoming competitive with fossil fuel, even not taking into account CO_2 emissions
- Off-grid installations continue to play an important role in developing countries

Future of PV



- The PV industry will continue to pursue cost reduction via economies of scale and improved efficiency (lab efficiency for monocrystalline Si is today at 25%)
- Thin-film technology is also closing the gap (lab efficiency for CIGS is now close to 22%)
- However it is not yet clear if Swanson's law can be maintained
- New materials and technologies (i.e. perovskite and DSSC) could hold the key to completely new applications like solar windows or flexible PV

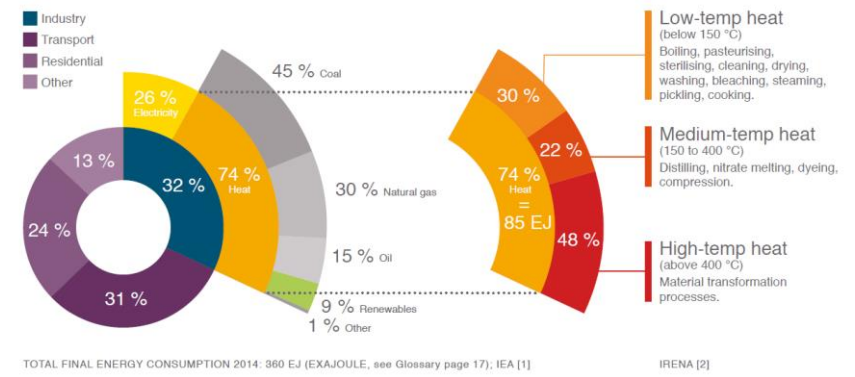
History of Solar Thermal

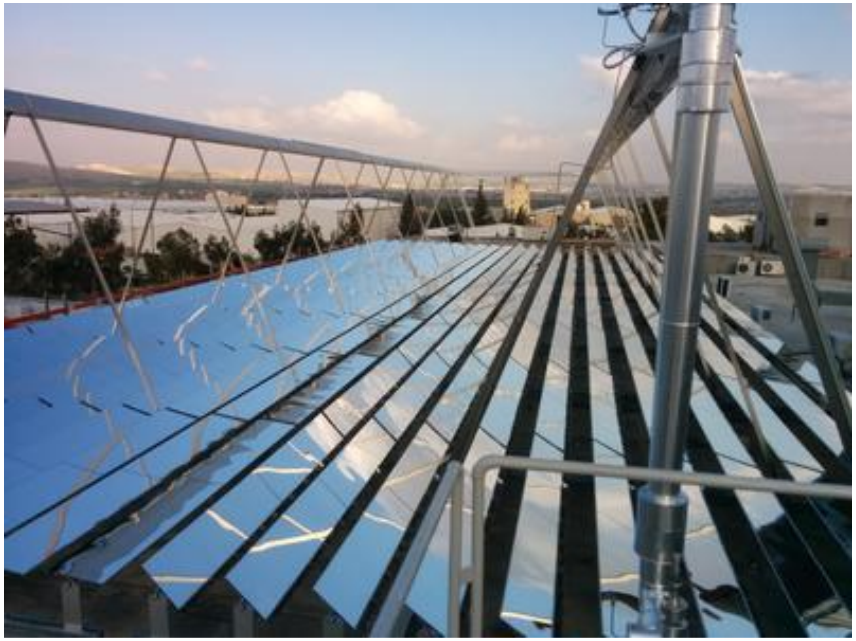
- A middle age legend tells that Archimedes first used mirrors to concentrate sun light and burn roman ships during the Syracuse siege of 214-212 BC
- In 1891 the American inventor Clarence M. Kemp patented the first water solar heater, named Climax
- At the beginning of the 20th century, cheap oil marginalised solar as energy source, but the 1973 Oil Crisis re-ignited public interest (power plants in USA)
- Today China dominates the residential market with evacuated tubes

Solar Thermal applications

- Large scale solar thermal installations concentrate solar light to heat steam above 400 ºC and produce electricity via turbines (Concentrated Solar Power: CSP)
- Single house solar water heaters provide sanitary hot water using vacuum tubes to increase efficiency at small scale
- Both these applications are under heavy pressure because of ever falling PV panels cost, which in the case of sanitary hot water production can be effectively combined with heat pumps

Industrial heat

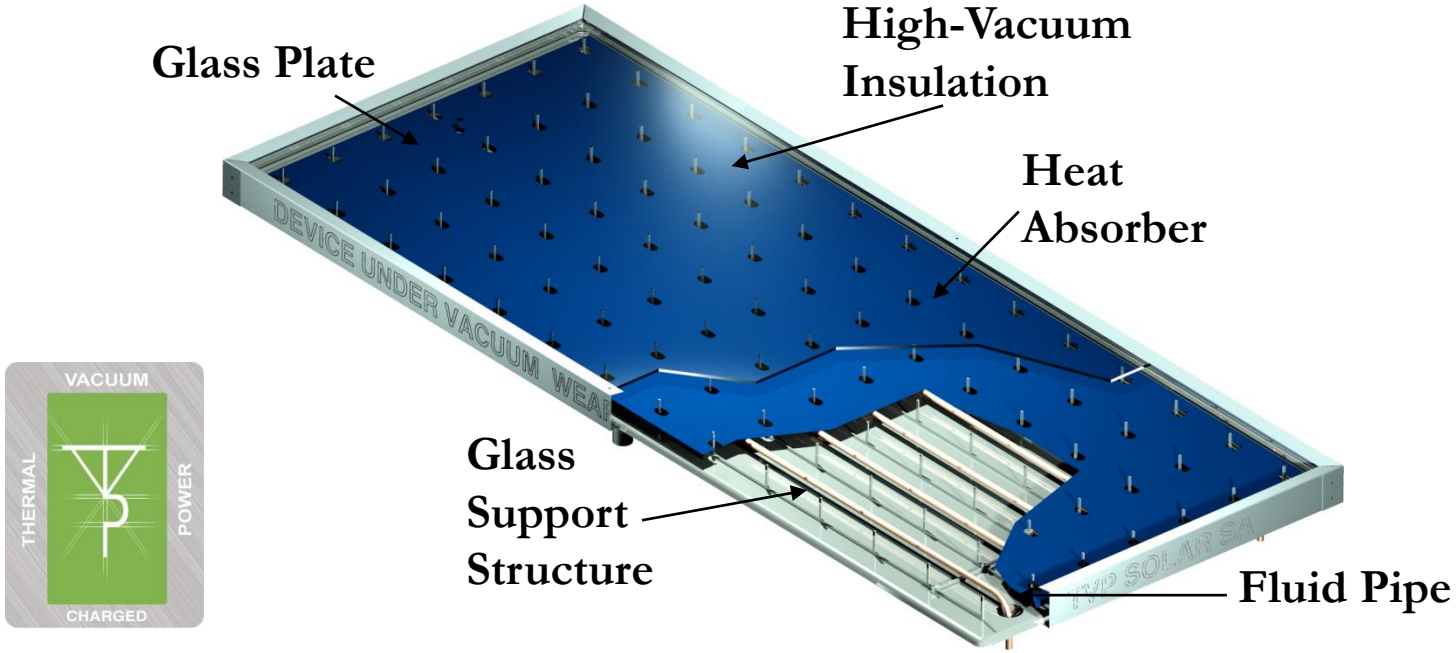




- Industrial heat for medium-temperature applications represents about 5% of global energy consumption
- This represents a tremendous opportunity for solar thermal, since PV efficiency is limited in heating at medium temperatures by the Joule effect (COP 1)
- Unfortunately light concentration to increase temperature has not proven effective for medium scale installations because of large OPEX related to moving parts and cleaning of the mirrors

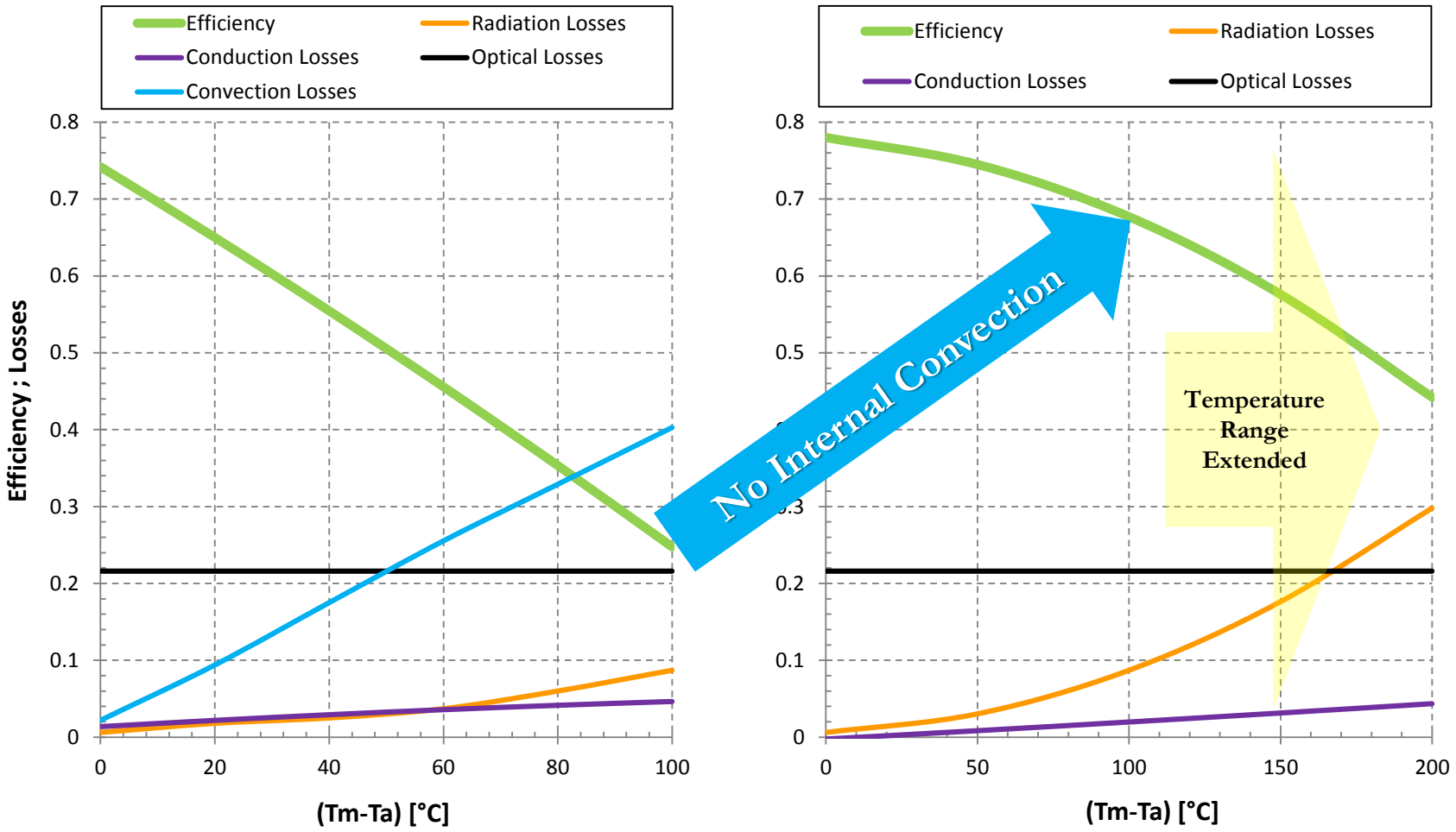
Thermal Vacuum Power Charged™ Panels

TVPC panels allow for the first time to take full advantage of high-vacuum insulation in a planar layout, offering high performance at competitive cost



TVP panels can operate with high efficiency up to medium temperature , without requiring concentration

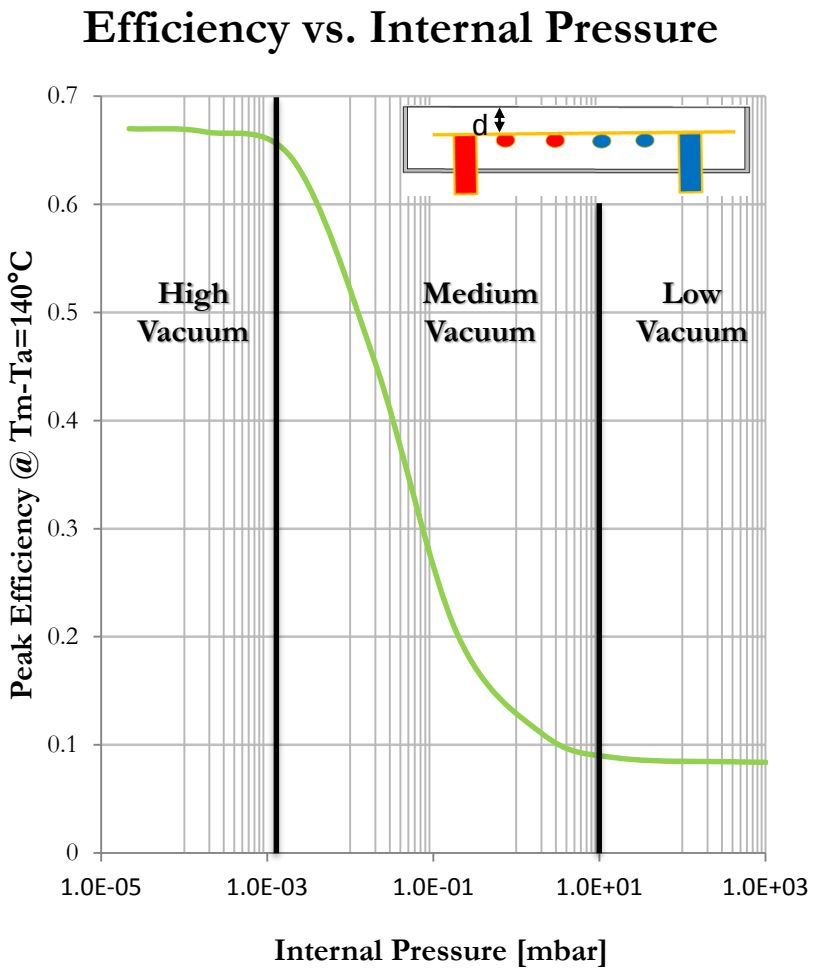
Vacuum does the magic…



Fiberglass insulation

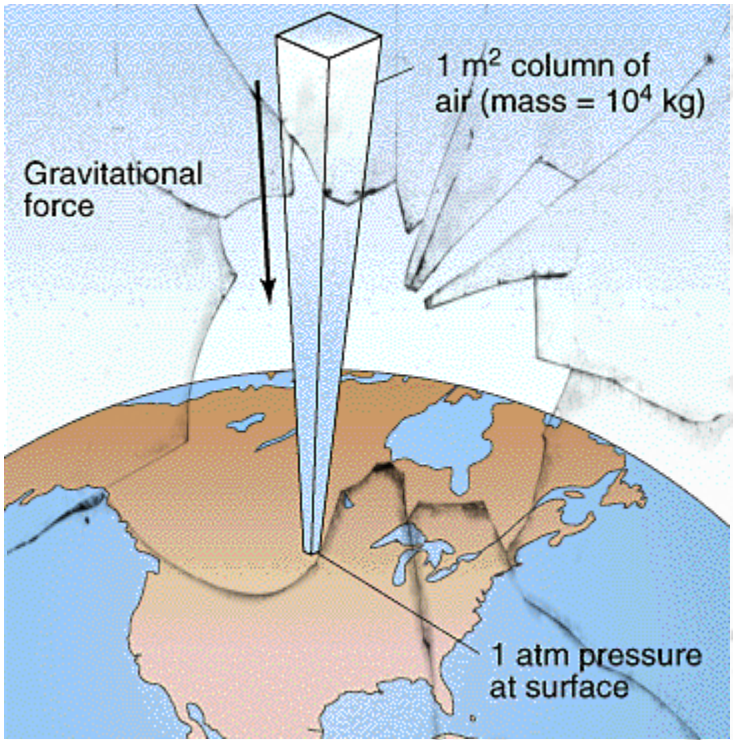
High-vacuum insulation

But, how much vacuum?



- Reducing pressure inside a solar panel envelope only slightly reduces internal convection until the mean-free-path of residual gas molecules gets longer than the gap between the absorber and the envelope (d)
- Under such condition (typically reached at around 10^{-1} mbar for d=1 cm), molecules collide with the walls more often than with each other and gas heat conductivity becomes dependent on pressure and surface only (not on gap width), disappearing below 10^{-3} mbar (high-vacuum)

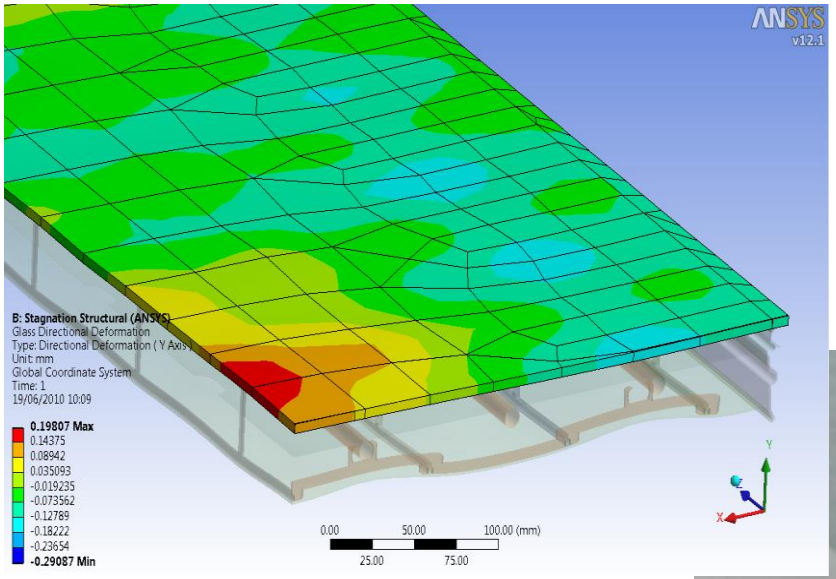
Technology challenges



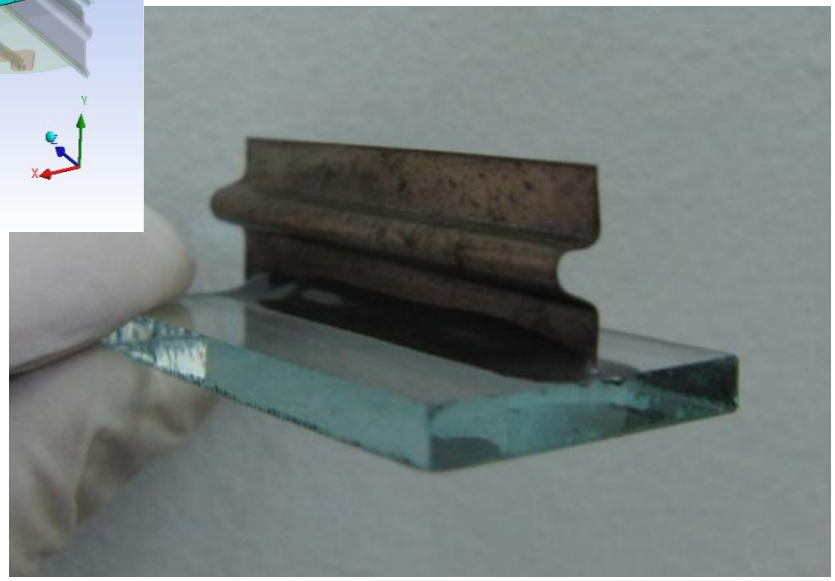
Supporting glass plate against atmospheric pressure (10 ton/m^2)

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

TVP Solar flexible glass-metal seal



A fully inorganic flexible glass-metal seal…



…made with display industry standard materials

TVP Solar self-regenerating getter pump

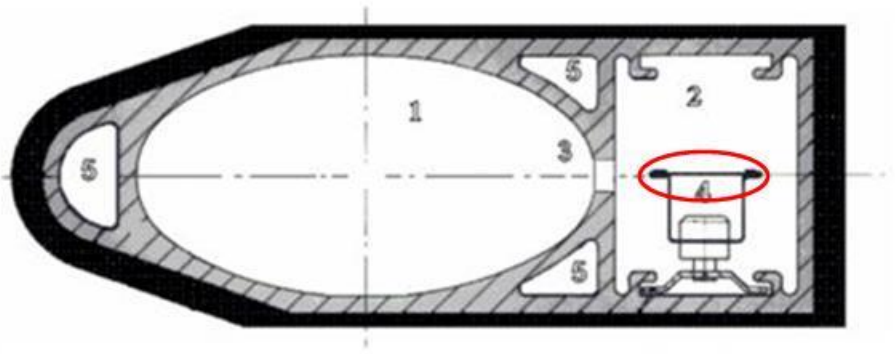
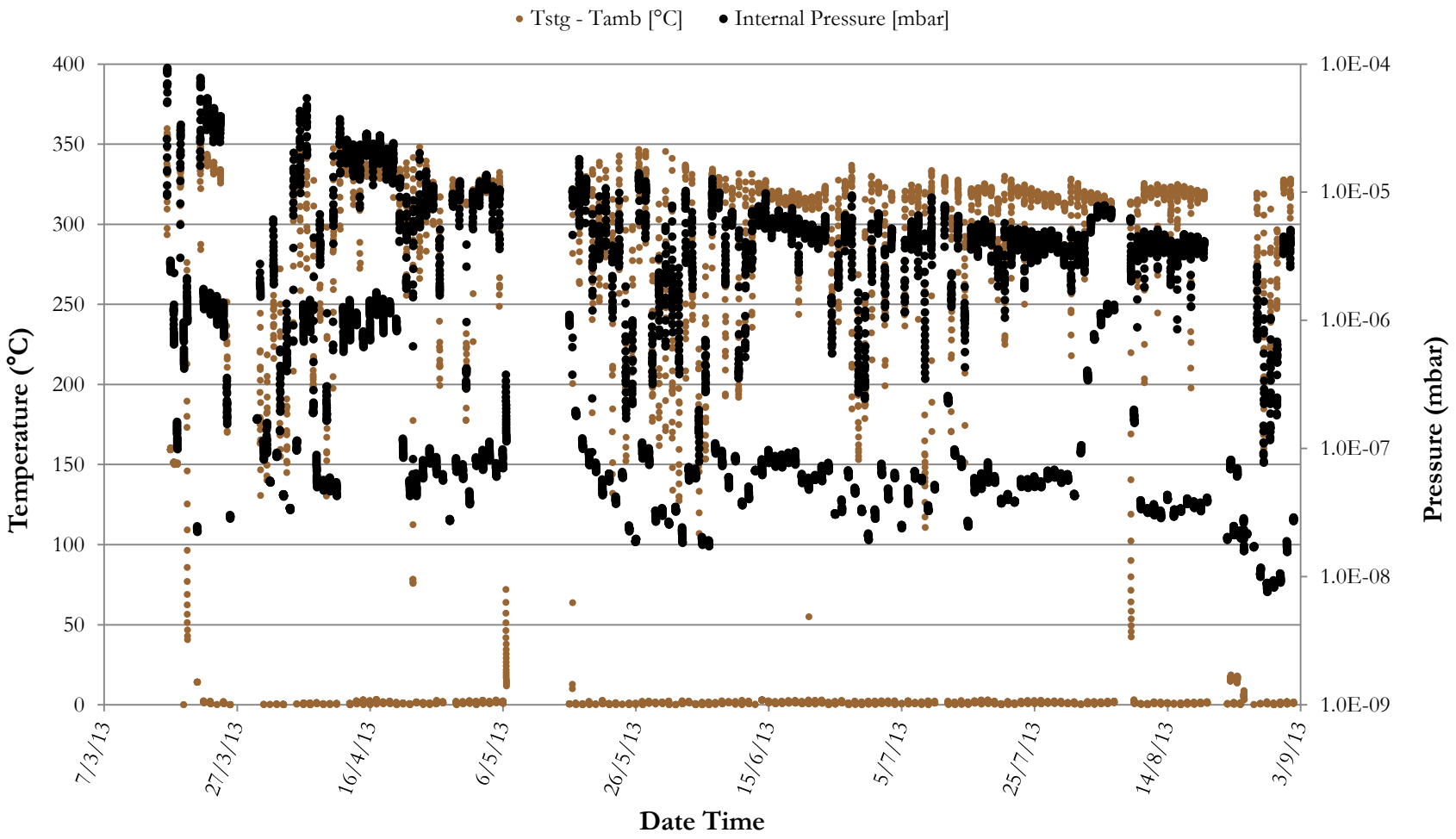
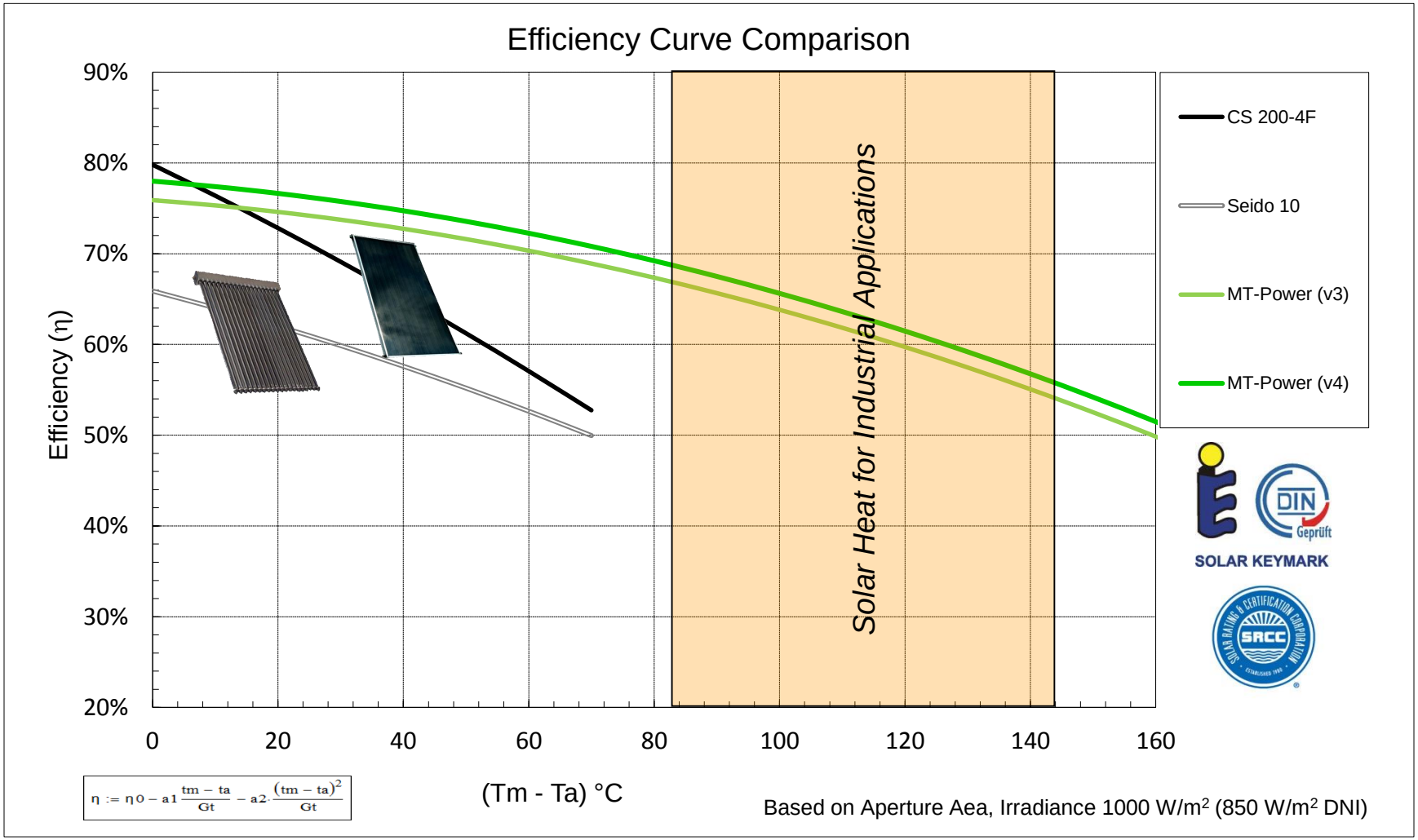


Fig. 5: Cross-section of the LEP dipole vacuum chamber: 1) chamber, 2) antechamber, 3) slot, 4) NEG strip and its support, 5) cooling channels

Vacuum improves with time…



MT-Power: peak efficiency



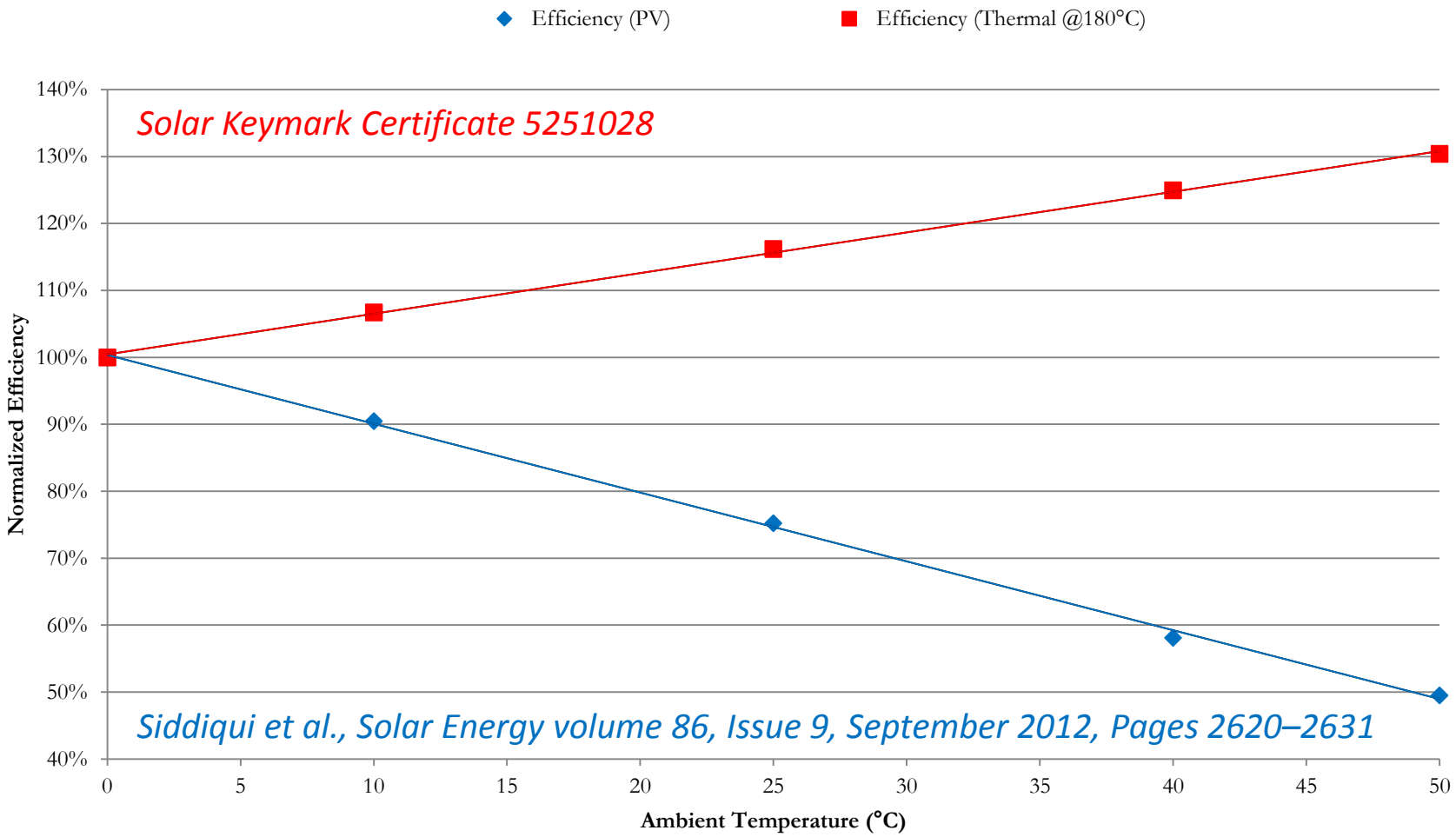
MT-Power: in action

TVP panels can be used to provide Solar Air Conditioning using Double Effect Absorption Chillers. This installation on top of an office building in Kuwait City provides cooling 24/7 via hybridization with electricity or liquid fuel

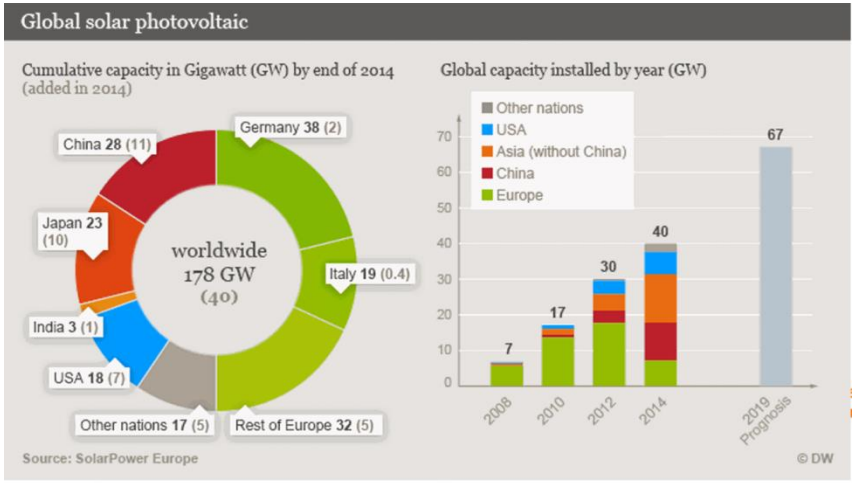
Solar Thermal o PV?

- Besides efficiency and cost the first thing to take into account when selecting a solar technology is the internal energy need
- Self-consumption maximization is in fact always the best rule to respect in order to reap maximum benefits
- A brewery will install solar thermal for its fermentation tanks heat needs, while a car park will install solar photovoltaic for charging its cars
- Quite often incentive policies can distort this picture...

Effect of Temperature

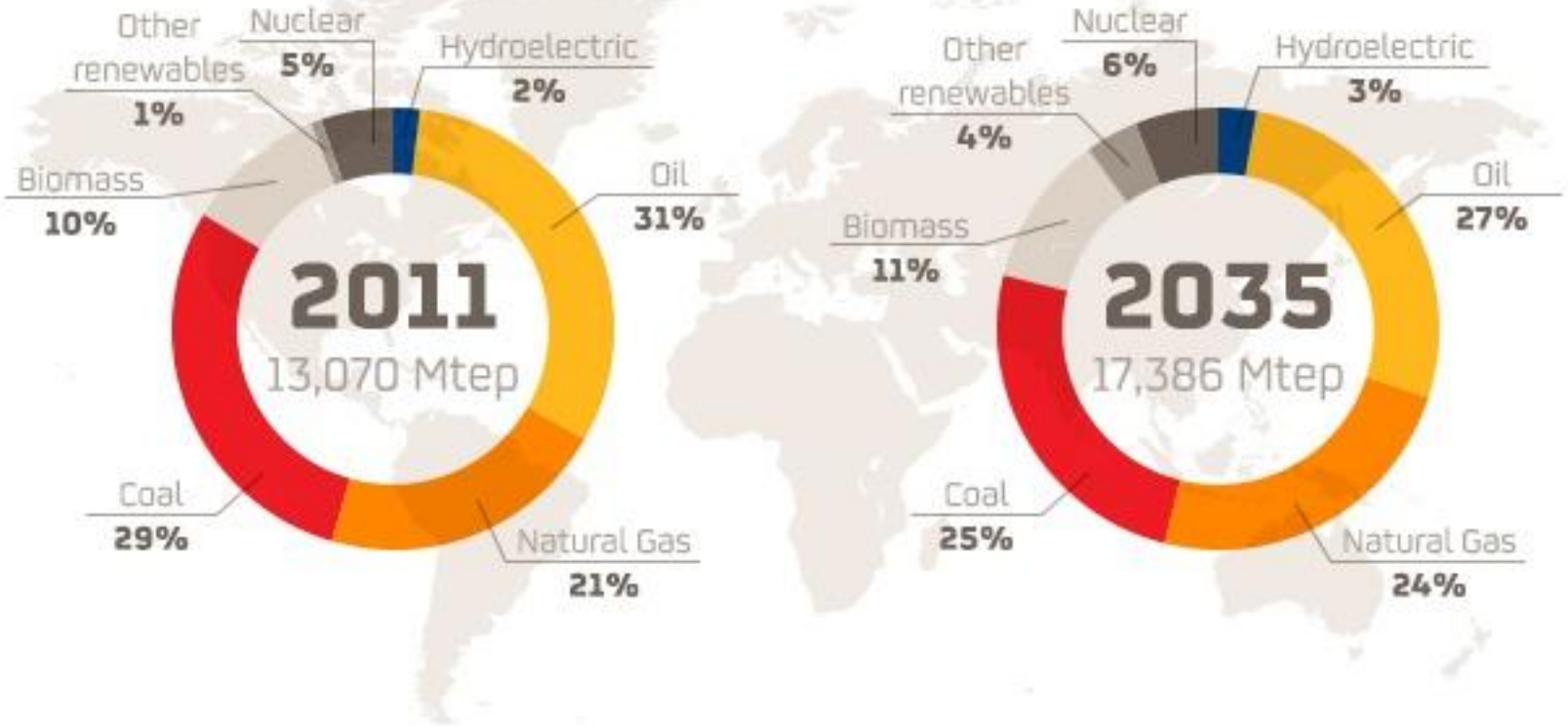


The solar industry of today



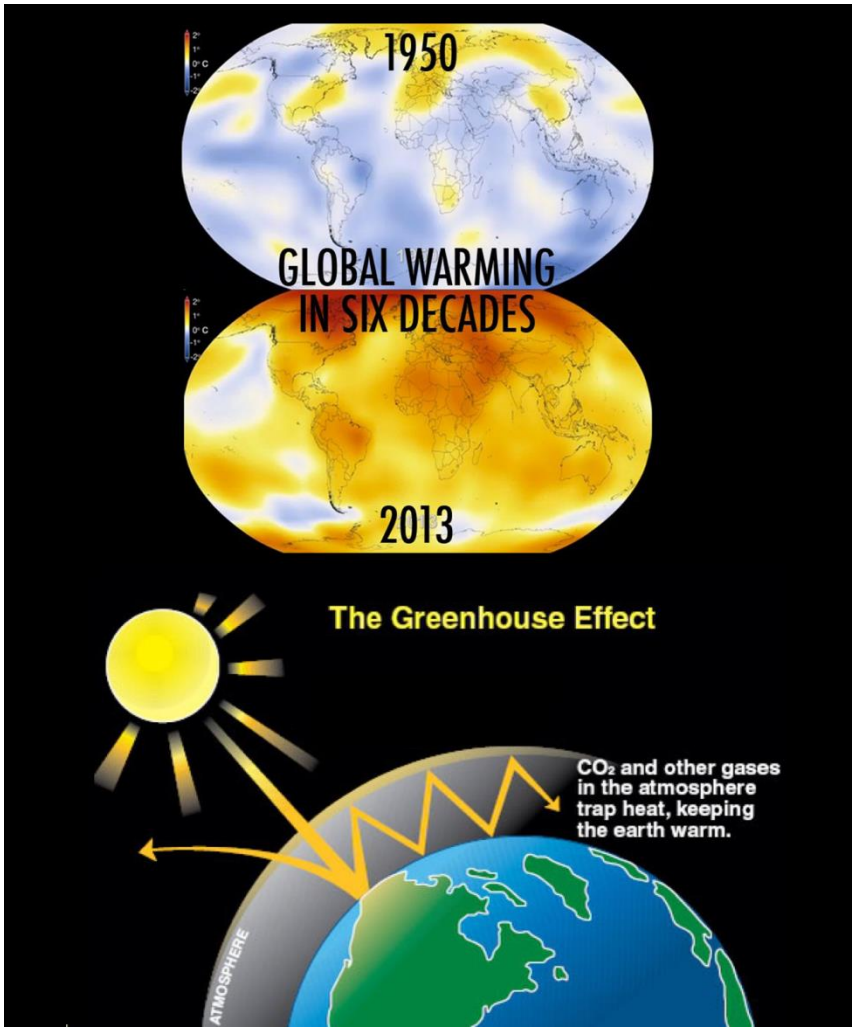
- The solar industry is worth today more than 100 billon $, out of which 80% for power generation (99% PV, CSP just 1% or less)
- Solar is still a small fraction of the whole renewable energy sources, but it has the greatest growth rate
- Slowly incentives schemes are loosing importance for market adoption and economic fundamentals are driving the growth
- Solar thermal is still mainly for residential use with most installations in China

Solar in the energy-mix of the future



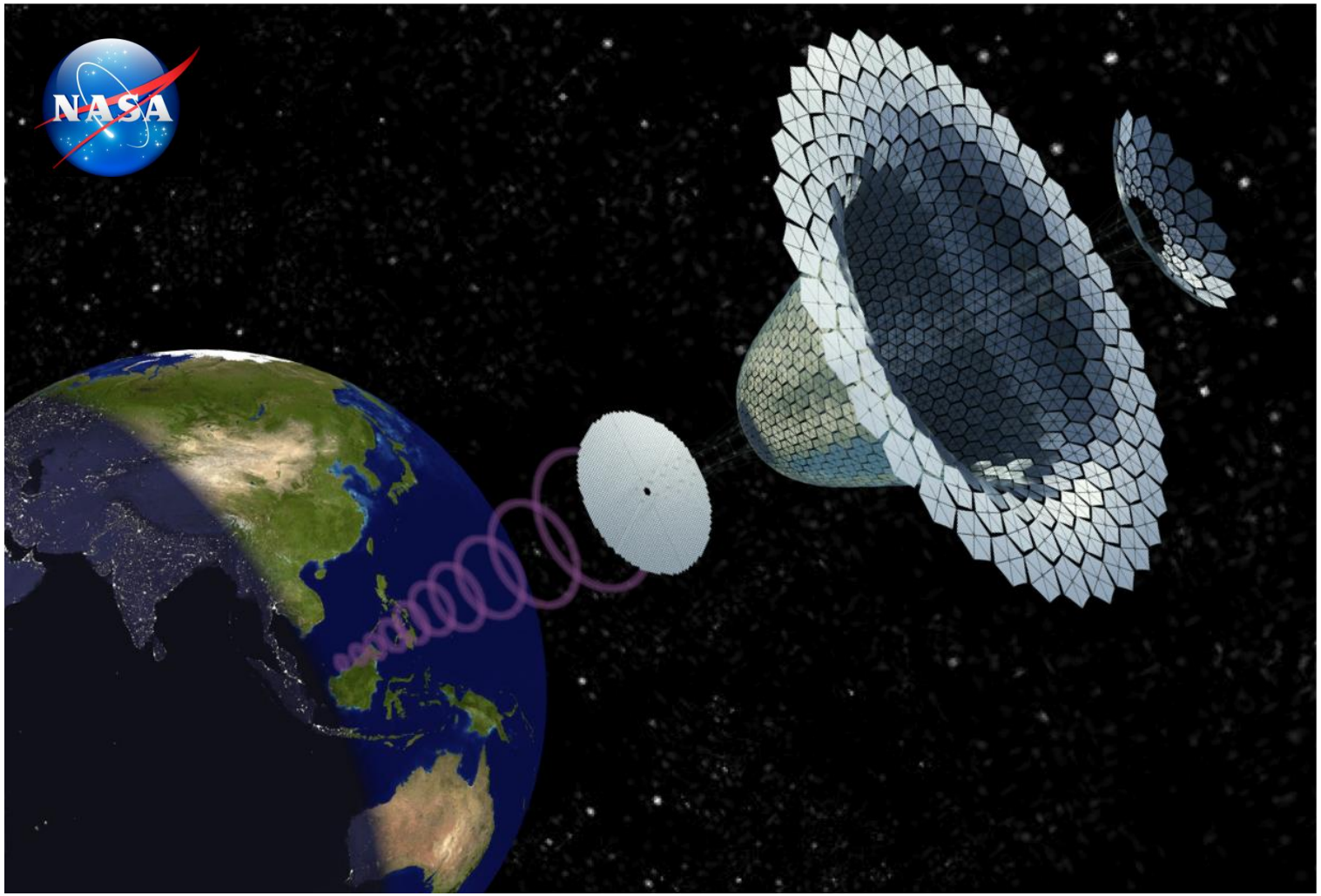
Source: International Energy Agency (WEO 2013) and Repsol Technical Secretariat Division

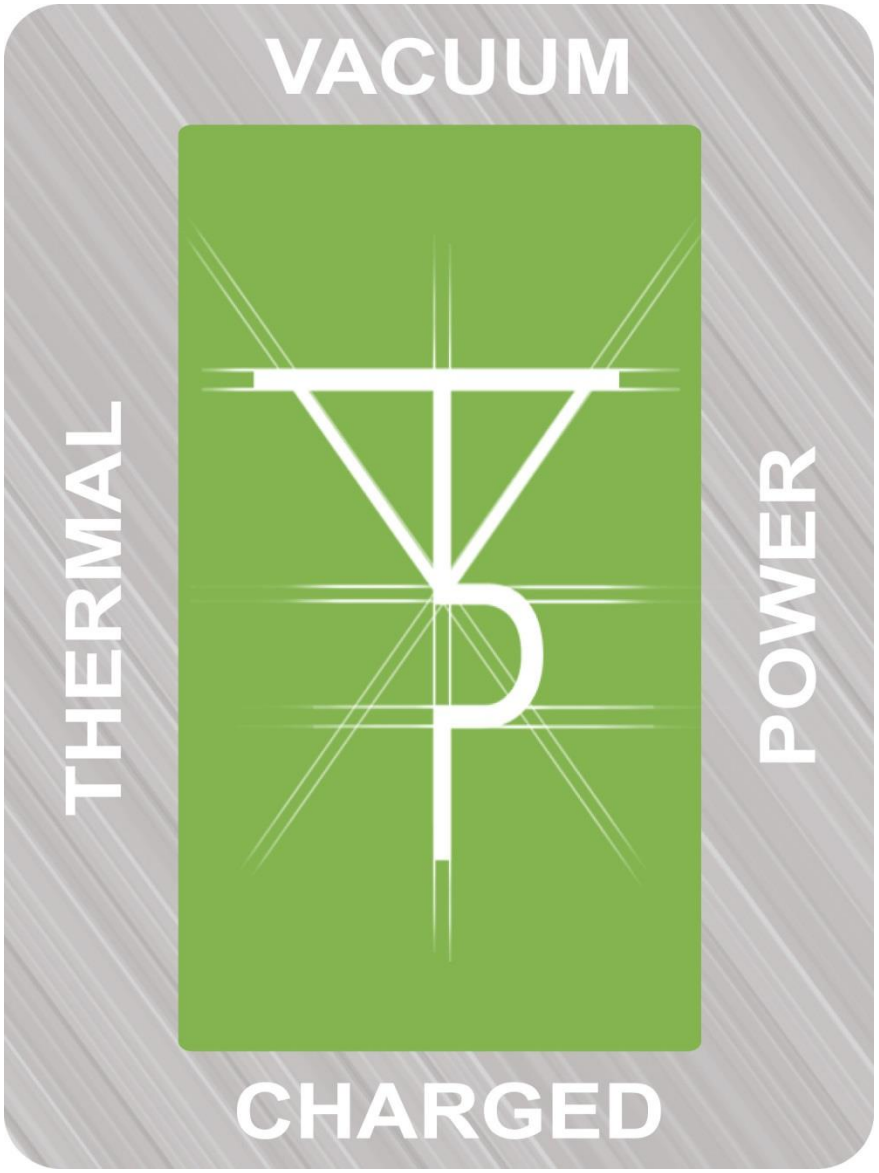
The role of Global Warming



- Global Warming is the phenomenom for which the average temperature of our planet is constantly increasing for the last 60 years
- 95% of scientists believe that this is caused by human activities via the Greenhouse effect
- After a first European agreement (Kyoto 1992), more recently USA and Cina have decided to reduce CO_2 emissions too signing the Paris agreement together with EU and onther 192 countries in 2015
- Following the election of President Trump the USA have notified intention to withdraw from the agreement in 2017

To infinity and beyond!

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