DOE | PHOTOVOLTAIC THERMAL (PVT)

October 2024

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1.0 Introduction

In 2015, the National Renewable Energy Laboratory (NREL) released a report on Photovoltaic-thermal (PV-T) technology which combined standard rooftop photovoltaic (PV) panels with waste heat recovery systems. As there are numerous efforts to utilize solar technology in a myriad of ways, this report begins with a working definition of PV-T, taken from the NREL report.

> "Photovoltaic–thermal (PV-T) technology consists of a typical solar PV panel, coupled with a solar thermal collector installed on the back of the PV panel to pre-heat domestic hot water (DHW) or ventilation air. This allows a larger portion of the solar energy incident on the collector to be turned into useful thermal and electrical energy. A primary feature of this system is that the efficiency of a PV panel decreases as the cell temperature increases. Water or air flowing through the thermal collector removes heat from the PV cells, allowing for more efficient operation. In addition, water or air heating and electricity can be produced within the same footprint, resulting in more efficient use of valuable roof space."[1]

Acronyms commonly used in the literature for photovoltaic thermal include PV-T, PVT and PV/T.

The use of PVT has grown in many parts of the world, but in the United States adoption has been slow. According to a 2020 publication by the International Energy Association (IEA), the U.S. had installed only 2 megawatts thermal (MW th) of PVT systems.[2] However, it should be noted that this 2019 study was based on information collected from a limited number of PVT manufacturers globally (N=26) including only one from the United states. A more recent 2024 publication entitled **Solar Heat Worldwide**[3] bases its results on data provided by 72 surveyed countries and ranks the U.S. higher. However, it is important to also note that globally, PVT is not defined in a uniform fashion which makes it difficult to secure good data. For example, some organizations, include "swimming pool heating" under PVT; whereas the U.S. does not.

The purpose of this report is to provide an introduction to PVT technology; to demonstrate how European and U.S. companies are developing and using PVT and to provide a glimpse of U.S. incentives for PVT.

2.0 PVT Systems Classification

This section examines the various ways in which PVT systems are classified, starting with a figure which depicts the essential components of a photovoltaic thermal system. Drawn from a 2019 publication by CAF Ramos, this figure represents the manner in which PVT systems integrate a PV module that converts solar energy into electrical energy and another module with high thermal conversion efficiency which employs a thermal fluid. "This optimization of solar conversion technology has the main objective of cooling the photovoltaic cells, for increased generation of electricity, while also resulting in useful thermal energy from the working fluid, therefore constituting a cogeneration equipment."[4]

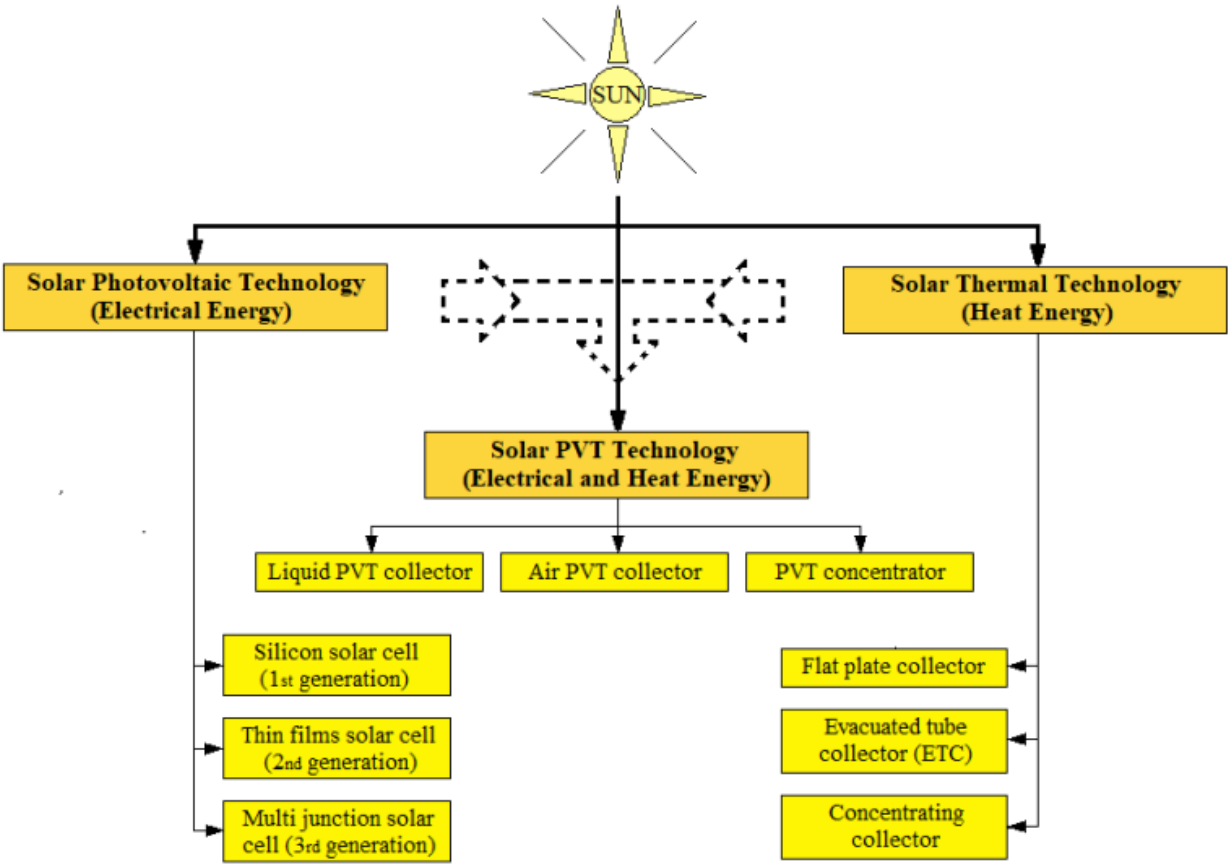


Figure 1: Types of Solar Technologies
Source: IOP Conference Series: Earth and Environmental Science[5]

The working fluid can be a liquid or air and according to the review by Ramos, "the thermal fluid is one of the most important selections to make."

2.1. Types of PVT Collectors

"PVT collectors combine the generation of solar electricity and heat in a single component, and thus achieve a higher overall efficiency and better utilization of the solar

spectrum than conventional PV modules. PVT collectors… are engineered to transfer heat from the PV cells to a fluid. In this way, this excess heat is made useful and can be utilized to heat water or as a low temperature source for heat pumps, for example. Thus, PVT collectors make better use of the solar spectrum.[6]"

In the 2020 publication by the International Energy Association four different collector types were highlighted: (1) WISC, (2) Covered, (3) Evacuated and (4) Concentration.. Additionally, an extensive recent review of PVT systems and collectors has categorized the "main types of PVT collectors" into liquid-based, dual air-water, air-based, building integrated, heat-pipe, and concentrated.[7]

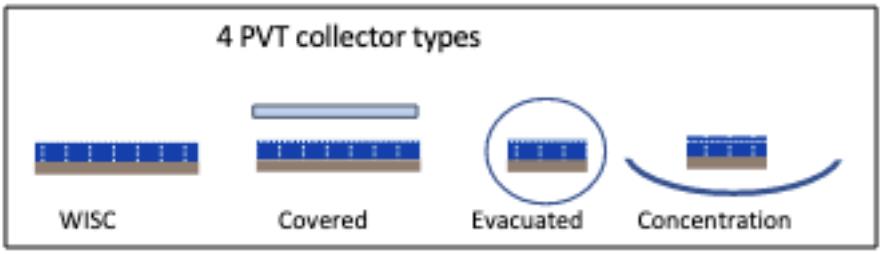


Figure 2: 4 PVT Collector Types
Source: IEA Solar Heating and Cooling Technology Collaboration Programme[8]

2.1.1 Uncovered PVT Collectors (WISC)

An uncovered PVT collector (which can also be referred to as unglazed or wind and/or infrared sensitive PVT collectors [WISC]), is normally comprised of a PV module with a heat exchanger component on the back. These PVT collectors are often prefabricated units. Occasionally products are presented as heat exchangers that will be retrofitted for off-the-shelf PV modules.[9] The following image shows a cross-section view of an uncovered PVT collector.[10]

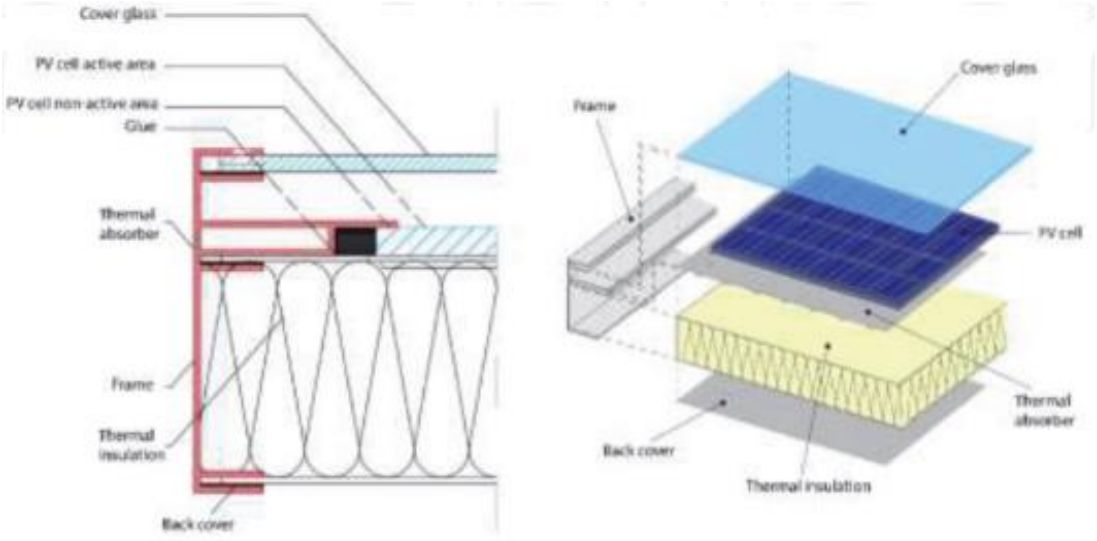


Figure 3: Cross-Section View of an Uncovered PVT Collector
Source: IntechOpen[11]

2.1.2 Covered PVT Collector

Covered PVT collectors have the same look as evacuated vacuum tubes or conventional flat plate collectors but "PV cells instead of spectrally-selective absorber coatings absorb the incident solar irradiance and generate an electrical current in addition to solar heat." As opposed to uncovered PVT collectors and PV modules, covered PVT collectors are capable of hitting higher temperatures. These operating temperatures can fluctuate between various applications and are dependent on working fluid temperature. For a swimming pool the average fluid temperature is 25 °C, while in a solar cooling system the average fluid temperature is 90 °C.[12]

2.1.3 Concentrating PVT (CPVT) Collector

A Concentrating PVT system lowers the necessary photovoltaic (PV) cell area. In turn, cells that have increased expense and efficiency can be used, such as multi-junction photovoltaic cells. According to the IEA SHC TCP:

> "Concentrator systems often require reliable control systems to accurately track the sun and to protect the PV cells from damaging over-temperature conditions. However, there are also stationery PVT collector types that use non-imaging reflectors, such as the Compound Parabolic Concentrator (CPC), and do not have to track the sun. Under ideal conditions, about 75 % of the sun's power directly incident upon such systems can be gathered as electricity and heat."[13]

2.1.4 Air PVT Collectors

An air PVT collector is made up of a thermal collector system and PV panel. In this type of system, thermal energy and electricity are generated at the same time.[14]

2.2. PVT System Classification Schemas

Many different representations are found in the literature to represent the essential components of a PVT system. The following figure is from an article by Sourav Diwania et al.

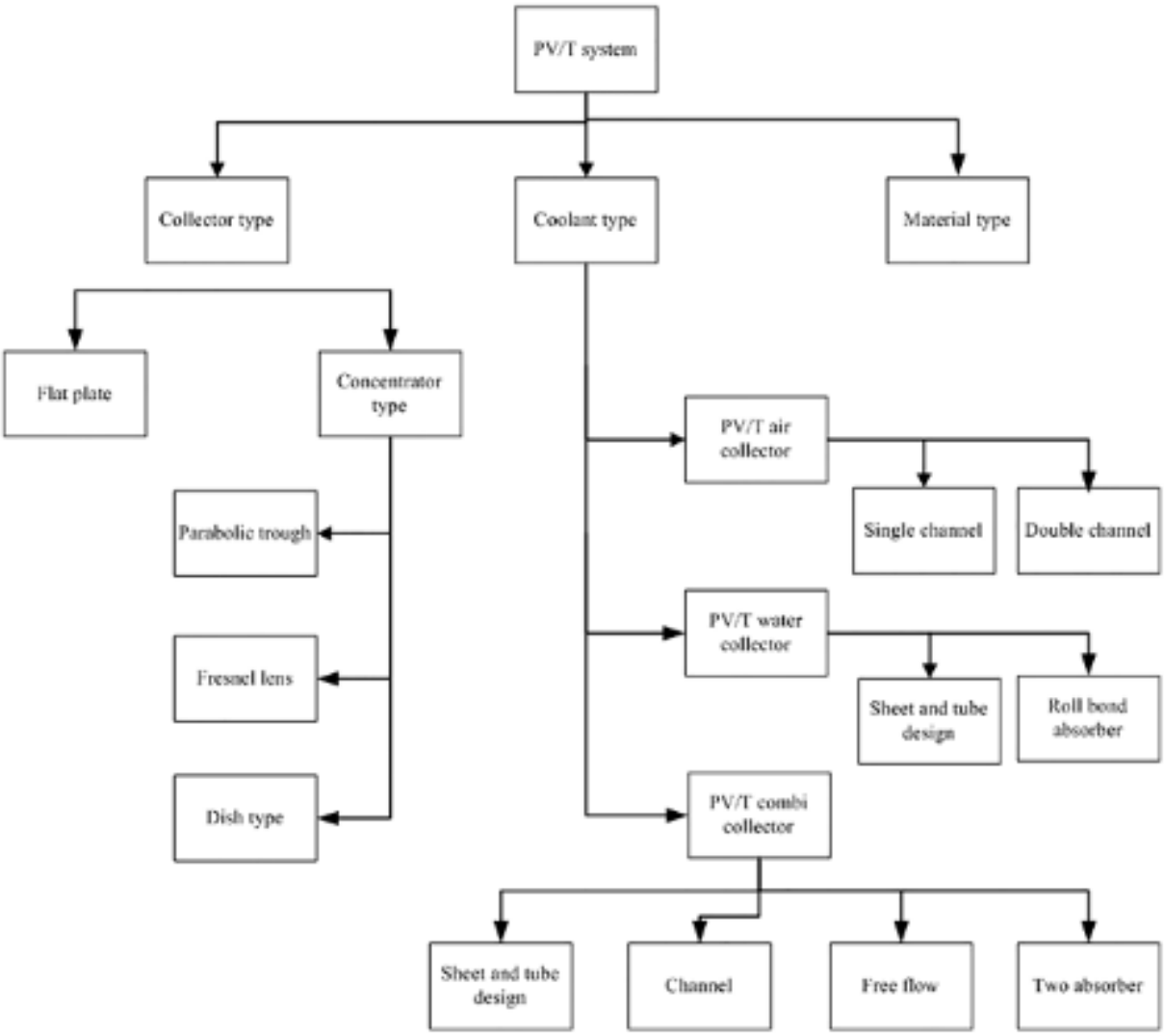


Figure 4: Categorization of PV/T Technologies
Source: International Journal of Energy and Environmental Engineering[15, 16]

The following year, a *Future Cities and Environment* article categorized PVT systems into conventional systems (air, water, concentrator, and bi-fluid) and novel-based systems (refrigerant, nanofluid, PCM [phase change materials], and heat pump).[17] In 2023, an overview of state-of-the-art hybrid PV-T collectors and their systems was provided in *Progress in Energy and Combustion Science*. The following figure provides a look at the types of PV-T collectors explored in the article, as well as their corresponding primary applications.

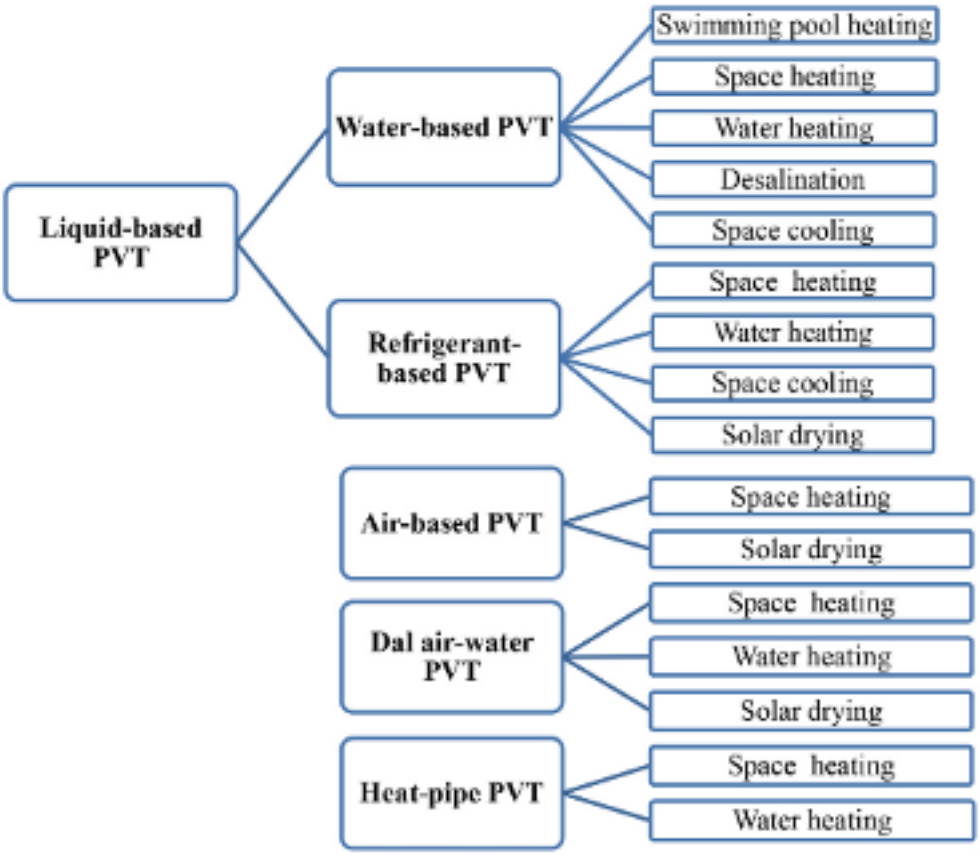


Figure 5: Application of PV-T Collectors as Included by María Herrando et al.
Source: Progress in Energy and Combustion Science[18]

A 2023 review of PVT technology published in *Energy Reports* provides another take on PVT system classification:

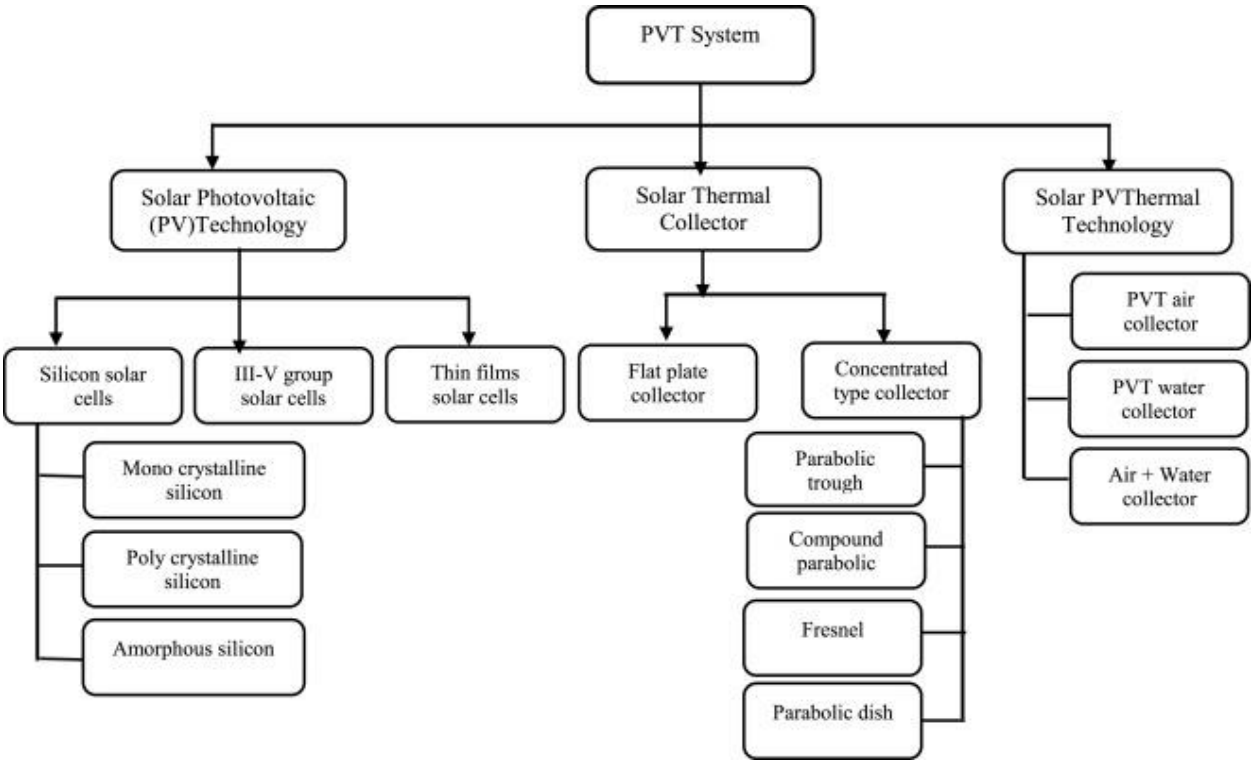


Figure 6: Classification of PVT System
Source: Energy Reports[19]

Şirin et al. (2023) categorized PVT systems in the following way:

- "Type of collector design: flat plate and concentrated
- Type of working fluid: water, air, other (nanofluid, mineral oil, bifluidic)
- Type of covered panel: glazed and unglazed
- End use: electricity + hot water production, electricity + space heating, electricity + ventilation, and other
- Type of PV: monocrystalline, polycrystalline, and multi-junction
- Type of fluid flow: forced and natural
- Application area: stand alone, and building integrated (roof, façade, window, Trombe wall)" [20, 21, 22]

2.3. PVT Applications

PVT technology can be used in many applications including residential,[23] industrial,[24] and even electric vehicles (EVs).[25] One commonly discussed application is Building-Integrated Photovoltaic Thermal (BIPV/T) systems which combine PVT with building-integrated photovoltaics for residential and non-residential buildings. Building-Integrated Photovoltaic Thermal (BIPV/T) systems "produce heat and electricity simultaneously from the same building surface area. When air is used as the heat recovery medium (BIPVT/a), the extracted thermal energy is available either for direct use for low

temperature applications (e.g. fresh air preheating), or through the mediation of a heat pump, for higher temperatures (e.g. space heating, domestic water heating)."[26]

The integration of PV in building structures can provide supply chain efficiencies, lowering system costs,[27] material and electricity savings,[28] increasing system efficiency, facilitating indoor heating, and hot water production.[29] The literature suggests that there is the potential for BIPVT to be a large renewable energy source in urban environments where systems could be installed as a façade or on a roof to aid with goals for sustainability. Non-residential and residential buildings (e.g., house and hospitals) alike can benefit economically from BIPVT systems due to the way these systems can meet flexible energy demands.[30] The following figure provides a visual representation of how BIPVT systems can be categorized.

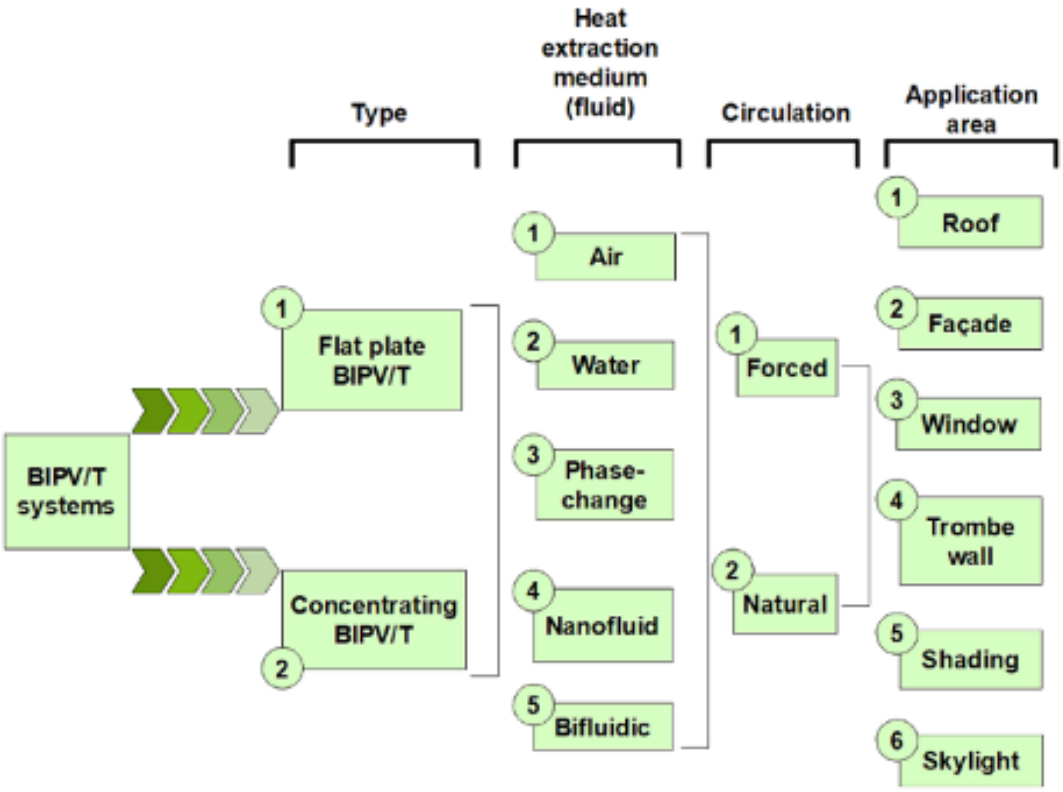


Figure 7: Categorization of BIPV/T Systems
Source: Applied Thermal Engineering[31]

According to REN21, another potential application for PVT systems includes dairy farming and livestock in the agricultural sector.[32]

3.0 Introduction to European PVT manufacturers

In this section examples of applications being developed by a number of European PVT manufacturers are highlighted. European PVT manufacturers have been expanding their factories in anticipation of an increase in demand. Two manufacturers which have been ramping up production are Abora Solar (Spain) and Sunmaxx PVT (Germany).[33] Other manufacturers explored in this section include Dualsun (France), Naked Energy (UK), Triple Solar (Netherlands) and Solarus (Netherlands).

3.1. Abora Solar

Founded in Spain in 2017, Abora Solar is one of the few manufacturers of covered PVT collectors in Europe. The company has a new type of PVT collector planned for market release in 2025 called "SHE" which stands for Solar Heat and Electricity. In anticipation of that release, Abora Solar has installed an additional production line in their manufacturing facility. The company's Founder and Managing Director confirmed that they sold 25,000 m2 of PVT collectors in 2023 and they are "expect a doubling of sales year-by-year."[34] Abora Solar has solutions for the following sectors: hotels, factories, hospitals, schools and more.[35] According to the company's website, the only partner in North America is Hydro Solar Innovation Energy located in Canada.[36]

Figure 8: View into Abora Solar's Production Hall in Zaragoza
Source: Abora Solar

Abora's Hybrid Solar Panel

Abora Solar manufactures a hybrid solar panel with aHTech® technology that enables simultaneous electricity and heat production. It features high-efficiency thermal collectors on the back and photovoltaic solar cells on the front, converting solar energy

into electricity and converting radiation into heat. The company manufactures the panel in Spain and says the panel's aHTech® technology reduces energy losses, making it "the most efficient solar panel in the world."[37] The product's technical specs can be reviewed here.

Figure 9: Abora's Hybrid Solar Panel
Source: Abora Solar

Sample Applications of Abora Solar's PVT Technology

Abora Solar's hybrid solar panel (PVT) technology is installed in a variety of buildings (e.g., hotels, multi dwellings, sport centers, factories, and nursing homes). In 2023, a hospital in Spain installed 58 PVT panels and 89 PV panels for combined electrical and thermal production.

Figure 10: Abora Solar Installation at CIBA Biomedical Research Center in Spain
Source: Abora Solar

Abora Solar also installs their hybrid panels in hotels to produce hot water and electricity. One example is a hotel in the Netherlands that installed 44 panels in 2023 to be used for hot water and electricity production. The system's electrical production is 14.546 kWh and its thermal production is 39.676 kWh.

Figure 11: Abora Solar Installation at a Hotel in Ruigrok, Netherlands
Source: Abora Solar

3.2. Dualsun

Dualsun is one of Europe's established manufacturers of uncovered PVT collectors. The company was founded in France in 2010.[38] Since 2013, over 40,000 DualSun installations have been completed in 25 countries. Projects have included covering homes, apartments, schools, public swimming pools, and even a soccer stadium.[39] DualSun is "the creator of the world's first certified hybrid solar panel, manufactured in France, for dual solar production: electricity on the front and hot water on the back."[40]

Recently, the company launched Spring4, the fourth generation of its PVT elements, replacing the polymer used in Spring3 with its in-house produced direct-flow aluminum absorbers. The metal absorber is mechanically fixed to the PV element with an aluminum bar and springs.[41] DualSun SPRING hybrid panels can supply buildings with heat and electricity. A water-to-water heat pump uses two water circuits: the primary circuit, which heats water, and the secondary circuit, which recovers heat from the sun and ambient air, which is then transferred to the back of the panel. The electricity generated can be used to power appliances or heat pumps or sold on the grid.[42]

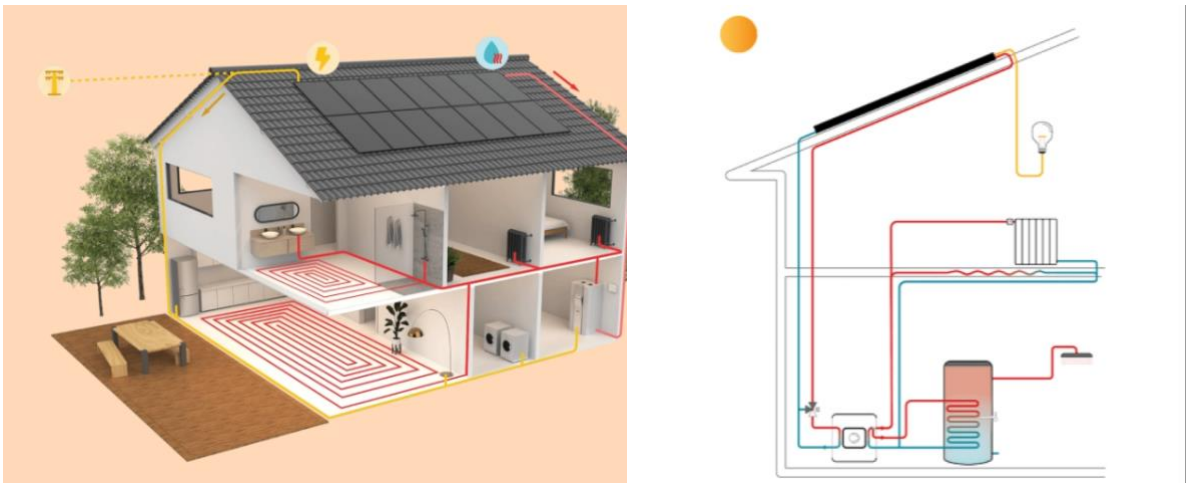


Figure 12: Solar Heating with Heat Pump
Source: DualSun

Datasheets and certifications can be found here. The majority of PVT systems have been installed in Europe, with systems also installed in Africa, Asia, Australia, Canad, and Central America.

Sample Applications of DualSun Hybrid Panels

One example is the installation of 18 hybrid panels on a building in Geneva, Switzerland. The building had solar thermal panels installed 20 years ago, but they were nearing the

end of their lifespan and were experiencing over-heating issues. The hybrid panels installed by DualSun served two functions: preheating domestic hot water and providing electricity to common spaces. The electricity is self-consumed within the building, making hybrid solar panels a more sustainable option as they generate electricity while continuing to produce hot water, all within a limited rooftop space.[43]

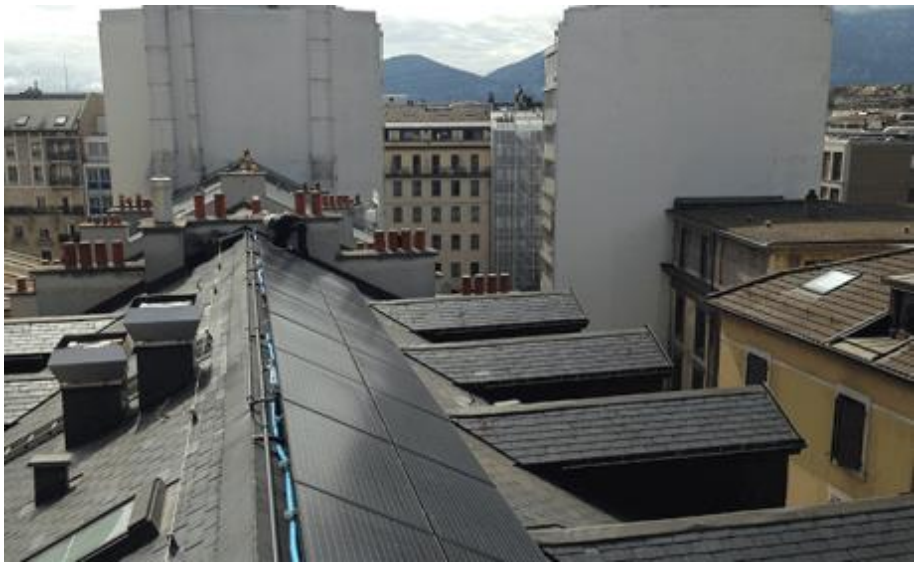


Figure 13: DualSun Hybrid Panels on Building in Switzerland
Source: DualSun

Another example is Europe's first solar-powered restaurant in Marseille. The project, completed in 2024, installed 4 DualSun SPRING4 hybrid panels and 3 DualSun FLASH photovoltaic panels for electricity and hot water production in order to make the restaurant completely energy autonomous.[44]

Figure 14: DualSun Hybrid Panels on Restaurant in Marseille
Source: DualSun

3.3. Naked Energy

Naked Energy, based out of the UK, developed Virtu products for commercial and industrial applications of customers with constant hot water and heat demand. Such consumers include hotels, multi-family apartments, social housing, schools, hospitals, food & beverage (F&B), textiles, and paper manufacturing. Virtu products, Virtu^{Hot} and Virtu^{PVT}, generate more energy per square meter than any other solar technology. These solutions are ideal for high-energy consumers with little available space for traditional solar.[45]

> There are two product models: VirtuPVT and VirtuHOT. Both products are modular and designed to be flexible and meet various levels of demand. Each model can be supplied with reflectors or without. VirtuPVT has a standard absorber angle of 35°and VirtuHOT can be manufactured with different absorber angle specifications at either -20°, 0°, +20°, +35° with the angle being dependent on the installation requirements.
>
> VirtuPVT delivers up to 4x more energy than solar PV, and more carbon savings for many public, industrial and commercial buildings that require hot water or other forms of heat. It also delivers lower running costs and better return on investment than standard PV systems.[46]

Additional case studies can be reviewed here.

Sample Applications of Naked Energy VirtuPVT

Naked Energy's VirtuPVT product is installed at the student housing for a London-based university as well as a UK national Innovation and Knowledge Centre (IKC), SPECIFIC.[47, 48] The student housing installation is a 139 m2 system that includes 60 VirtuPVT solar collectors (in addition to the company's VirtuHOT tubes) which supply power and heat for the students that live there:

Figure 15: VirtuPVT Installed in London-based Student Housing
Source: Naked Energy[49]

Naked Energy has installed 40 VirtuPVT panels at the SPECIFIC Active Office where they heat water and generate electricity at the building.

Figure 16: VirtuPVT Installed at SPECIFIC
Source: Naked Energy[50]

3.4. Sunmaxx PVT

Founded in 2021, Sunmaxx PVT is located in Germany and offers uncovered PVT collectors, which are usually operated in combination with heat pumps. The company purchases PC cells and laminates PV modules in-house. The company, however, is hesitant to disclose the production method of the direct-flow aluminum absorber and how it is fixed to the PV panel.[51] Sunmaxx PVT modules apply the latest generation solar cells with the highly developed systems from the automotive industry for thermal management.[52] The datasheet can be downloaded here.

In 2023, the company was awarded the “Solar Keymark” certification, validating the company’s “adherence to rigorous industry standards in solar technology.” Solar Keymark is a European certification for solar thermal products that guarantees that the products meet strict industry standards and have successfully passed extensive climate tests.[53]

Sunmaxx has been making significant strides in the industry to expand the use and increase the efficiency of PVT modules. In March 2024, Sunmaxx partnered with Wagner Solar to distribute PVT modules. Wagner Solar is a wholesaler of photovoltaic and solar thermal energy as well as a manufacturer of mounting systems.[54] Then, in June 2024, Sunmaxx PVT and Oxford PV launched the "Solar Hammer" solar PVT module. This partnership introduced the first use of perovskite-on-silicon tandem solar cells in a photovoltaic thermal module. The "Solar Hammer" module, with all major components crafted in Germany, offers high conversion efficiency and represents a step forward to increasing European competitiveness in solar PV technologies. Wilhelm Stein, CEO of

Sunmaxx, stated, “We believe this technology will be valuable for homeowners, businesses and municipalities looking to meet their decarbonization goals quickly, and that this partnership will be valuable for Germany’s solar industry.”[55]

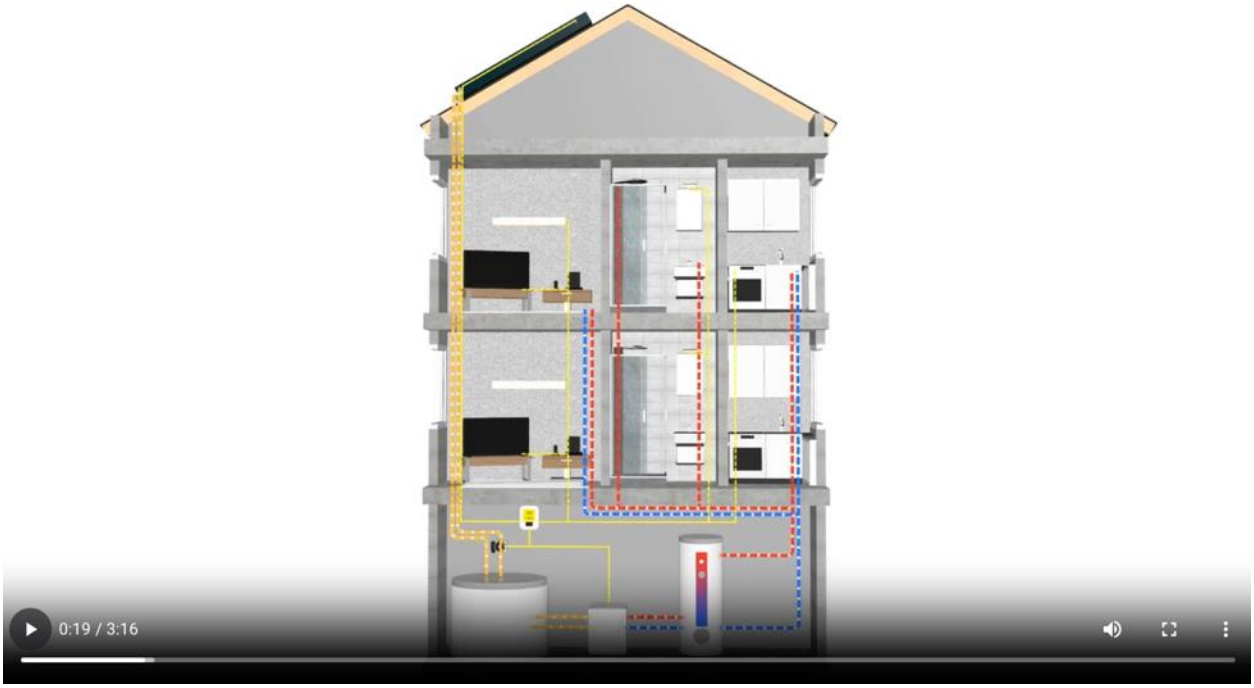


Figure 17: SunMaxx How It Works Video
Source: SunMaxx

3.5. Triple Solar

Triple Solar is based out of Amsterdam with offices in Germany, UK, Ireland and Denmark. The company offers two types of PVT systems: hybrid, for existing houses and all-electric, for new homes (as gas is no longer used in new builds per legislation in the Netherlands).[56] The Triple Solar® PVT-heat pump panel features a heat exchanger with aluminum fins and copper pipe. A coolant, glycol, absorbs ambient heat and transfers it to the heat pump. The heat pump converts this heat into usable heat for heating and hot water. The system’s solar panel makes it possible to supply a building with electricity, along with heat and hot tap water.[57] A catalog of projects can be reviewed here.

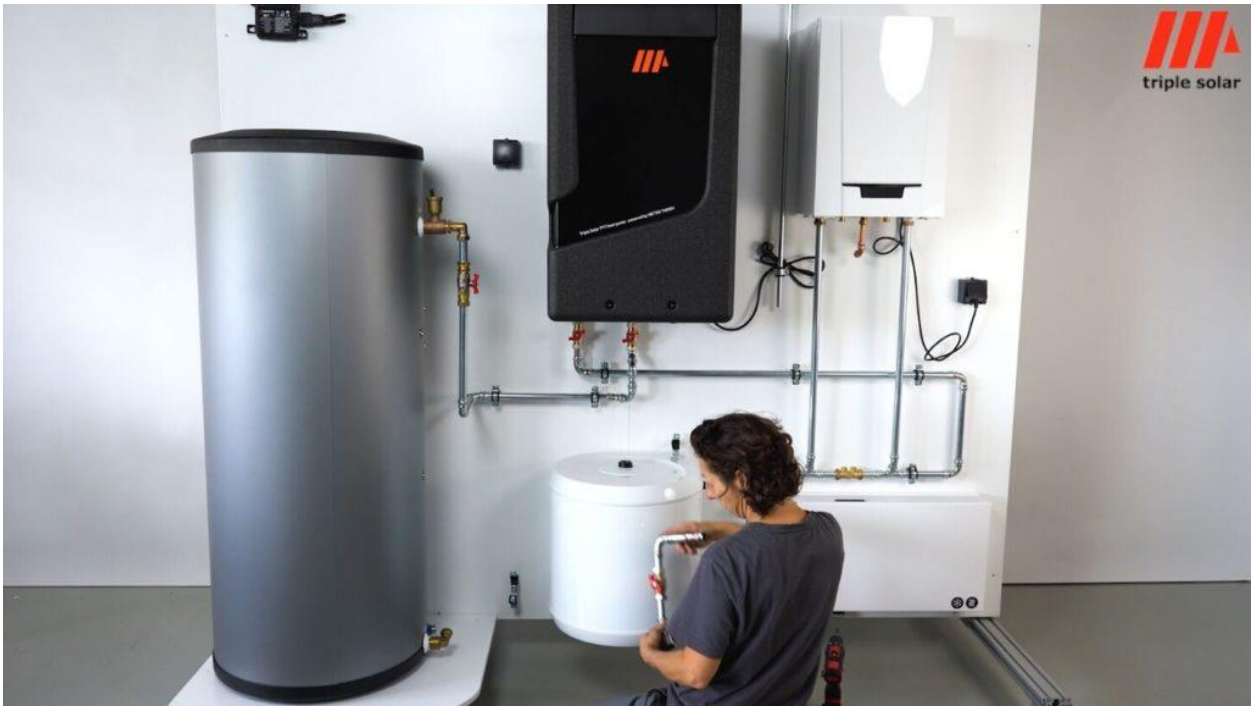


Figure 18: Triple Solar PVT System
Source: Triple Solar

Sample Applications for Triple Solar PVT Systems

Triple Solar has installed PVT systems for a variety of applications including utility buildings, monasteries, new build homes, and house boats among others. One example is the installation at the University of West London. Triple Solar installed 580 PVT heat pump panels at four University sites. The company's project page states this is the world's largest PVT installation.[58]

Figure 19: Triple Solar's PVT System on The University of West London
Source: Triple Sun

Another example is the installation of PVT heat pumps and PV solar panels on 93 apartments in the Netherlands.

3.6. Solarus

Founded in 2020 in the Netherlands, Solarus provides a solution to industrial and commercial clients addressing the needs of hot water demands while having a limited solar collection area. The product, marketed as a hybrid solar solution, is tailored to the clients' needs[59] and promises four times more energy than photovoltaics in a comparable space. The solar panels used (aHTech®) are designed and manufactured by Abora Solar in Spain.[60,61] The hybrid solar panel is deemed "the world's most cost-effective solar panel with an efficiency of 89%" and "produces the same energy as 4 photovoltaic panels."[62]

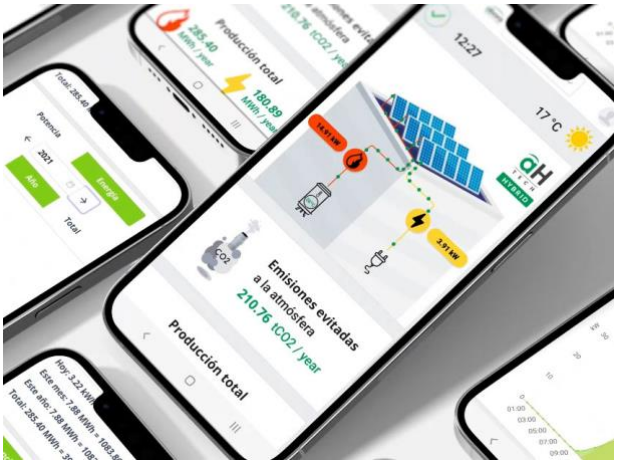


Figure 20: Image of App from Solarus Website
Source: Solarus

4.0 Introduction to PVT Manufacturers in the U.S.

Although global reports say very little about U.S. PVT manufacturers, there are a number of U.S. companies which have been actively working in this field for a number of years including Green CHP, ICARUS, Power Panel, Solar Wall and SunDrum Solar.

4.1. Green CHP™

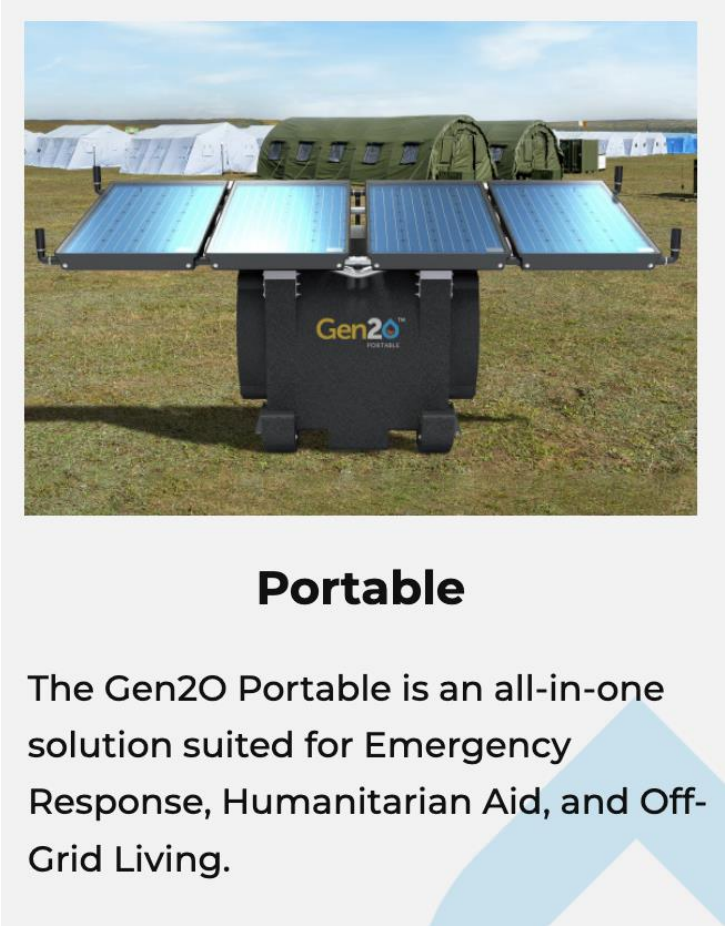
Integrated energy solutions provider and U.S.[63] company, Green CHP, provides a hybrid thermal solar panel-based solution for companies to lower the cost and utility dependence that is associated with electricity and hot water.[64] Green CHP's solar PVT system works by changing solar irradiance into usable heat, in addition to electricity. A list of case studies shows the variety of ways that Green CHP's systems have been used and the cost savings realized by a food processor, a brewery, and a hotel among others. As solar is used to generate the heat and electricity in the Green CHP systems there are no greenhouse gas emissions.

4.1. Icarus RT

San Diego, CA[65] company Icarus RT's technology transforms PV arrays into hybrid PV/T solar + storage systems.[66] THE Icarus Quartet serves a number of markets including multi-family housing, waste treatment, industrial and agriculture. The company's patented heat extractor reduces surface temperature and increases power output.

4.2. PowerPanel

PowerPanel, located in Oxford, Michigan, offers a range of photovoltaic thermal (PVT) products that are aimed for industrial and commercial application (e.g., non-governmental organization (NGOs), hospitality, healthcare, and government[67]).[68] For example, the the Gen$_2$O Portable, is suited for emergency reponse, humanitairn aid and off-grid living. It provides solar powered electricity hot, water and water filtration all in one, portable unit. In fact, at a Febrary 2024 Conference this system which is being used in Ukraine at medical facilities earned recognition at the Natural Disaster Conference. It was one of the six finalists out of 300 entrants for the"Cost Effective Mitigation Product of the year."[69] Other products include the Gen$_2$0 Integrated which provides all the benefits of PVT but without being on the roof. This is ideal for apartment buildings and hotels.



Source: PowerPanel

4.3. SolarWall by Conserval

SolarWall's offices are located in Toronto, ON and Amherst, NY. The company's PV/T systems work by installing PV panels on top of SolarWall panels:

> "The PV panels convert solar radiation into an electric current that can be used on-site, stored for later use, or fed back to the electrical grid for financial incentives. The majority of the solar radiation striking the PV panels, however, is lost as heat energy […] The SolarWall or SolarDuct system doubles as the PV-racking system and draws the excess heat away from the PV modules, significantly increasing their electrical output. The heat generated from the PV and solar thermal collector panels is used to heat the building's fresh air supply. The existing HVAC intake fans draw this fresh, solar-heated air through micro-perforations in the SolarWall panels, through insulated mechanical ducting, and into the HVAC units."[70]

SolarWall PV/T have been installed in a number of universities, laboratories and elementary schools

4.4. SunDrum Solar

SunDrum Solar based in Hudson, MA[71] manufactures collectors that capture thermal and electrical energy.[72] SunDrum Collectors are mounted behind PV panels, where they cool the panels and transport collected heat to an integrated heat pump.[73] SunDrum provides technology for applications in commercial, industrial, residential sectors (e.g., home water heating, home pool heating, HVAC, hospitality, multifamily, dormitory, brewery, and food processing).[74]

5.0 Federal/State Incentives for PVT Utilization in the U.S.

Incentives are important, not only for reducing cost, but for encouraging potential customers to try new technologies. In the 2024 Solar Heat World report the impact that subsidies can have on market adoption was clearly noted.

> "After experiencing steady growth averaging 9% annually between 2017 and 2020, followed by an all-time high of 13% in 2021, the trend took a sharp turn in 2022. The decline, driven by the end of subsidies for PVT in certain countries, led to market slumps of 51% in 2022 and 30% in 2023."

Although this quote was NOT referencing the United States, the U.S. has done little in the way of incentives to encourage growth of the PVT market. As a result awareness if this technology is quite limited.

5.1. Federal Solar Tax Credit (Business)

The investment tax credit (ITC) and production tax credit (PTC) are available for nonprofits, businesses, and entities that possess solar facilities. These facilities can include concentrating solar-thermal power (CSP) energy generation and photovoltaic (PV) technologies. ITC and PTC are detailed below.

> "The **investment tax credit (ITC)** is a tax credit that reduces the federal income tax liability for a percentage of the cost of a solar system that is installed during the tax year.
>
> The **production tax credit (PTC)** is a per kilowatt-hour (kWh) tax credit for electricity generated by solar and other qualifying technologies for the first 10 years of a system's operation. It reduces the federal income tax liability and is adjusted annually for inflation."[75]

The following table provides a look at the value of these credits based on the year.

Table 1: Summary of Investment Tax Credit (ITC) and Production Tax Credit (PTC) Value Over Time

			Start of Construction						
			2006 to 2019	2020 to 2021	2022	2023 to 2033	The later of 2034 (or two years after applicable year[a])	The later of 2035 (or three years after applicable year[a])	The later of 2036 (or four years after applicable year[a])
ITC	Full rate (if project meets labor requirements[b])	Base Credit	30%	26%	30%	30%	22.5%	15%	0%
		Domestic Content Bonus				10%	7.5%	5%	0%
		Energy Community Bonus				10%	7.5%	5%	0%
	Base rate (if project does not meet labor requirements[b])	Base Credit	30%	26%	6%	6%	4.5%	3%	0%
		Domestic Content Bonus				2%	1.5%	1%	0%
		Energy Community Bonus				2%	1.5%	1%	0%
	Low-income bonus (1.8 GW/yr cap)	<5 MW projects in LMI communities or Indian land				10%	10%	10%	10%
		Qualified low-income residential building project / Qualified low-income economic benefit project				20%	20%	20%	20%
PTC for 10 years ($2022)	Full rate (if project meets labor requirements[b])	Base Credit			2.75 ¢	2.75 ¢	2.0 ¢	1.3 ¢	0.0 ¢
		Domestic Content Bonus				0.3 ¢	0.2 ¢	0.1 ¢	0.0 ¢
		Energy Community Bonus				0.3 ¢	0.2 ¢	0.1 ¢	0.0 ¢
	Base rate (if project does not meet labor requirements[b])	Base Credit			0.55 ¢	0.55 ¢	0.4 ¢	0.3 ¢	0.0 ¢
		Domestic Content Bonus				0.1 ¢	0.0 ¢	0.0 ¢	0.0 ¢
		Energy Community Bonus				0.1 ¢	0.0 ¢	0.1 ¢	0.0 ¢

a "Applicable year" is defined as the later of (i) 2032 or (ii) the year the Treasury Secretary determines that there has been a 75% or more reduction in annual greenhouse gas emissions from the production of electricity in the United States as compared to the calendar year 2022.

b "Labor requirements" entail certain prevailing wage and apprenticeship conditions being met.

Source: Office of Energy Efficiency & Renewable Energy, Department of Energy[76]

In order to use these credits, the system must reside in the U.S. or U.S. territory, utilize primarily new equipment, and cannot be leased to an entity that is tax exempt.[77] More information on these business solar tax credits can be accessed here.

5.2. Federal Solar Photovoltaic Tax Credit (Residential)

The residential solar photovoltaics federal investment tax credit is defined in detail below.

> "The federal residential solar energy credit is a tax credit that can be claimed on federal income taxes for a percentage of the cost of a solar PV system paid for by the taxpayer. The installation of the system must be complete during the tax year

> Solar PV systems installed in 2020 and 2021 are eligible for a 26% tax credit. In August 2022, Congress passed an extension of the ITC, raising it to 30% for the installation of which was between 2022-2032. (Systems installed on or before December 31, 2019 were also eligible for a 30% tax credit.) It will decrease to 26% for systems installed in 2033 and to 22% for systems installed in 2034. The tax credit expires starting in 2035 unless Congress renews it. There is no maximum amount that can be claimed."[78]

This tax credit applies to the below:

- "Solar panels or PV cells
- Solar water heaters
- Energy storage devices with a capacity of 3 kWh or more
- Contractor labor expenses, including site preparation, assembly or initial installation
- Permit fees
- Inspection costs
- Developer fees"[79]

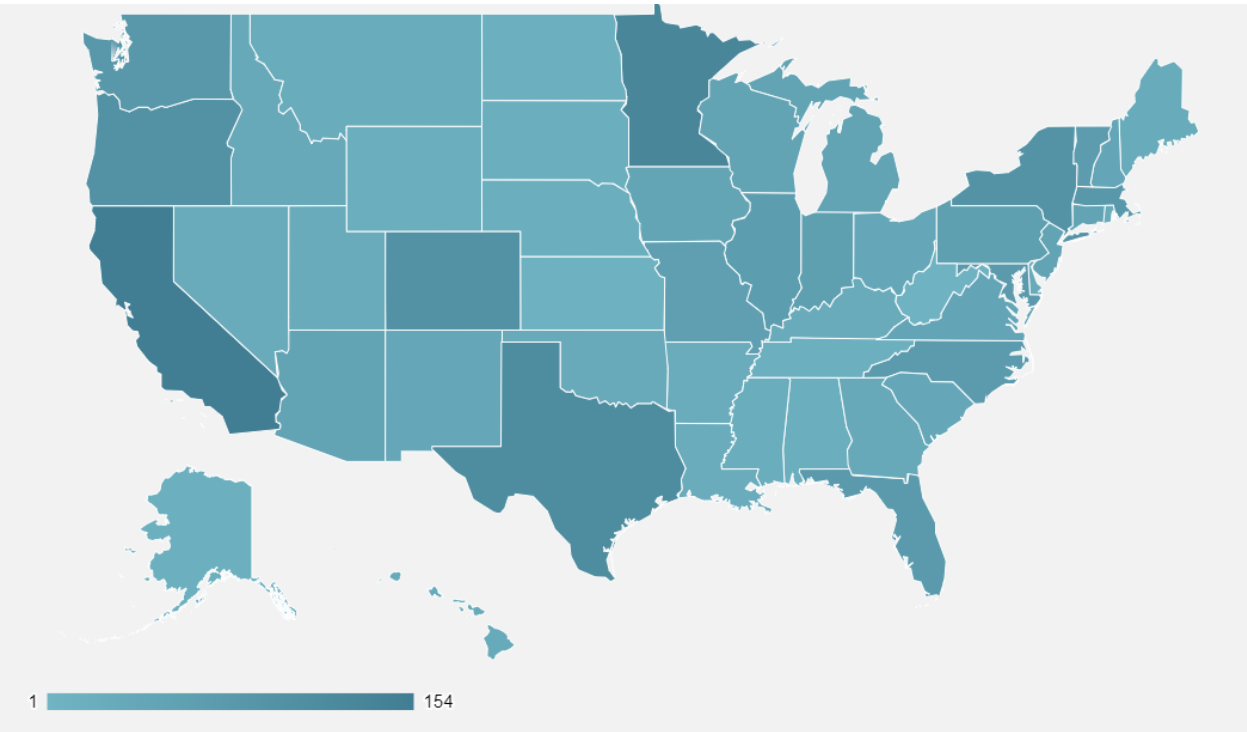
Eligibility for the federal residential solar energy credit depends on a variety of factors. The PV system need to be / have been installed between the range of January 1, 2017 – December 31, 2034. The system must be at an individual's U.S. residence and must be owned by said individual. A person is also eligible if they bought an off-site community solar project interest, under certain guidelines. Additionally, the PV system needs to either be new, or in its first use.[80] An overview of residential tax credits can be found here.

5.3. State Incentives

Although it varies from state to state, there are tax credits and government rebates available to incentivize solar system purchase. The Solar Renewable Energy Certificate (SREC) from the Environmental Protection Agency (EPA) Green Power Partnership is also available in certain states. Forbes explains how these SRECs work:

> "SREC markets operate based on renewable energy certificates that symbolize the rights to non-power aspects of renewable electricity generation. These SRECs represent each megawatt-hour generated from solar systems. In states with SREC markets, homeowners and businesses with solar systems can lower their energy costs by selling associated SRECs to utility companies. Supply and demand determine the monetary value of an SREC, with much of the demand coming from electricity suppliers needing to comply with their state's Renewable Portfolio Standard (RPS) or pay a compliance premium."[81]

DSIRE, featured in the previous section, also provides information on renewable policies and incentives by U.S. state through an interactive map. By clicking on a state, a user can access a list of these policies and incentives, which can be further explored through a variety of links on the site.



Follow this link to access interactive chart

Figure 21: Database of State Incentives for Renewables & Efficiency: Interactive Chart of Policies & Incentives by State

Source: Database of State Incentives for Renewables & Efficiency[82]

What is unclear from the description of the technologies which can benefit from these incentives is if installers know about PVT and if the incentives relate strictly to the solar aspect of the PVT system.

6.0 Summary and Conclusion

The use of PVT has grown in many parts of the world, but in the United States adoption has been slow. The purpose of this report is to provide an introduction to PVT technology; to demonstrate how European and U.S. companies are developing and using PVT and to provide a glimpse of U.S. incentives for PVT. What surfaces in this review is that there is very little data publicly available about PVT and PVT manufacturers in the U.S. In part, this appears to be caused by differences in nomenclature. It is often unclear if what is

being discussed is or is not PVT. Terms such as “solar cogeneration,” “photovoltaic thermal hybrid solar collectors,” “solar thermal technology,” and many others populate the market. Using a definition such as the one originally provided by NREL is therefore helpful as a starting point.

A preliminary look at the information available regarding U.S. incentives confirms that the focus is on solar installations. However, with PVT, this is but half the equation. Although there are separate incentives for solar installations and for heat pumps, it is unclear what types of incentives are available for PVT systems. In other words, if a homeowner wished to install a PVT system, would there be an incentive for the solar component, but not for the installation of the PVT collector system?

Research regarding the cost benefit of PVT systems in industrial, multi-family dwellings and government buildings within the U.S., would go a long way towards raising the profile of PVT as a means to reduce CO_2.

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