Highlights of Legal Face of PVT Systems in European Countries

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Abstract: The use of renewable energy sources (RES) is an important issue supported all over the world, especially in Europe. States provide cash and in-kind incentives for the use of RES. These incentive systems vary from country to country, region to region, and even from technology to technology used.

Increasing incentives or supports are very important for solar energy. To use a technology, no matter how successful it is, it is essential to have legal infrastructures that support it, at least not prevent it. It is possible that there are technologies that cannot be put into practice quickly simply because their value is not easy to understand. The existing support and incentives, both for RES-Eletricity and for RES-Heating, in the different countries are significantly different both in terms of amounts and in terms of the diversity of financial mechanisms.
The hybrid solar technology PVT is still very recent in commercial terms. Given the scarce information on the legal framework for PVT systems, this paper addresses this issue at the level of RES systems to produce both electricity and heating.
Keywords: *Solar energy, PVT technology, viability, incentives, legal framework*

1. INTRODUCTION

The use of renewable energy sources (RES) is an important issue supported all over the world, especially in Europe. States provide cash and in-kind incentives for the use of RES. These incentive systems vary from country to country, region to region, and even from technology to technology used [1]. To use a technology, no matter how successful it is, it is essential to have legal infrastructures that support it, or at least not prevent it. Hybrid solar technology (PVT, i.e. Photovoltaic (PV) and Thermal (T)) is an emerging technology. Therefore, while there are incentives for PV and thermal in Turkey, there are no incentives for PVT technology. Legal frameworks cannot follow these systems that are constantly evolving and changing. Increasing incentives or support is very important for solar energy, especially for PVT.
PVT systems are used in several applications: single-family and multi-family houses, hotels, campuses, public services, hospitals, agricultural and industrial processes, and even district heating [2].
A hybrid system costs less than a photovoltaic system plus a separate thermal system (PV+T combination). The PVT system costs a little more than a thermal system (since it includes photovoltaic), but the economic savings achieved by additional photovoltaic production means that most facilities (where a thermal plant would be installed) choose for PVT when they know its advantages. Also, it is important to bear in mind that the installation of PVT systems is not economically viable in every type of installation. Viability is ensured in buildings with a need for hot water, as it surely also consumes electricity. In these places, PVT is clearly more profitable than other solar technologies, with paybacks between 4 and 6 years being common [2].
The trade-off between the higher cost of a PVT collector and that of separate PV or T collectors must be balanced by the value of the heat or electricity produced on the same occupied area for the system owner. The heat produced can be delivered to a heating network, used onsite or stored in heat storage devices. The electricity produced can be delivered to a grid, used onsite or stored as either electricity or converted to heat. If the electricity is self-consumed, the savings can deeply enhance the Return on Investment depending on the local electricity price [1].
Currently, one of the main problems is to balance the high and growing demand for energy with the sustainable use of resources and the reduction of greenhouse gases (GHG) emission, to reduce the consequences resulting from energy production. The most effective way to resolve this issue is to promote energy production using renewable sources. This objective is so important at the European level that the European Parliament and the European Council issued a joint directive (Directive 2009/28/EC of 3 April 2009) which establishes the conditions for increasing the share of energy using RES establishing an average share for the European Union of 20%, without prejudice to ambitious targets for each Member State (MS). The central objective is "to reduce the Community's GHG emissions and its dependence on energy imports", together with "increasing energy efficiency". The Directive "sets mandatory national targets for the global share of energy from renewable sources" [1,3].
The improvement of energy efficiency is a key objective of the community. Buildings have an impact on the environment, leading to an increasingly global concern to try to mitigate the effects as effectively as possible.
The European Union (EU) is concerned to promote, as much as possible, the reduction of these impacts on the environment, imposing on all MS legal rules that increasingly reduce the use of fossil energy in the air conditioning of buildings, through: Reduction of the energy needs of buildings; Primary use of renewable energy sources in buildings and Promotion of greater flexibility in energy use by citizen communities.
The increased investment in energy production using renewable sources faces two major problems [1]: i) the high cost of technologies that allow the production of renewable energy; and ii) the unique characteristics of regions and countries that must be considered when choosing the type of source or sources to be used. Regulators from different countries and regions have at their disposal a significant set of regulatory instruments, all of them with different

application and with advantages and disadvantages. The main objective of these instruments is the replacement of energy production from non-renewable sources by energy production from renewable sources. Two objectives derive from this main objective: i) the promotion of technological development; and ii) the reduction of transaction and administration costs, to keep consumers receptive to renewable technologies. However, it is important to mention that the specific characteristics of each region and country require a careful analysis to implement the most appropriate instrument or combination of instruments.

With the COVID-19 (and post-COVID) manufacturing changes, the GHG emission has become one of the most vital social economics issues. The clean energy and climate change associations have spent decades tackling a crisis that has been unfolding in motion [1,3,4]. For example, the Paris Agreement puts forward to reinforce the worldwide response to the threat of climate change by limiting the mean global temperature growth at a maximum of 2°C in comparison with pre-industrial levels. The EU's nationally determined contribution under the Paris Agreement aims to decrease the GHG emission by at least 40% by 2030 in comparison with 1990 levels. Meanwhile, the World Green Building Council has issued a new vision to reduce 40% GHG emissions by 2030 and achieve 100% net zero emission buildings by 2050 [4]. Solar energy is one of the most promising renewable resources, which can solve the challenges associated with the climate change and environmental contamination. In terms of current solar energy technologies, photovoltaic-thermal (PVT) system is one of the most efficient owing to its stability, non-polluting, security and good visibility features.

Besides this introduction, this paper has a structure of four more chapters. Chapter 2 highlights the most important aspects of PVT technology. Chapter 3 addresses the feasibility of PVT systems vis-à-vis the installation of both PV and T systems considering the energy produced and the costs involved. Chapter 4 highlights the legal framework and incentives existing in several European countries. The last chapter is the conclusion.

2. PVT TECHNOLOGY HIGHLIGHTS

Hybrid solar panels (PVT) are being developed since 1970. PVT systems combine in the same panel the functions of PV collectors and T collectors, being a technology that simultaneously convert incident solar radiation into electrical energy and thermal energy [2,5]. This type of technology has several advantages over the use of only PV or T, since:

- Generate quantities of electrical and thermal energy per square higher than the amounts obtained when using PV collectors and separate T collectors;
- They are aesthetically more appealing (PVT are a more harmonious than the PV+T separate systems);
- The installation cost is lower, since only one collector is installed instead of two (PV+T).

Photovoltaic solar collectors of the PVT panels have PV cells made up mostly of silicon, in the form of monocrystalline, polycrystalline, or even amorphous silicon crystals. The electrical performance of PVT panels is directly related to the composition of their PV cells. Thus, there are several types of PVT collectors on the market with diverse configurations. However, two main classes can be specified [2,5,6] (Fig. 1):

- PVT collectors with concentrators (CPVT);
- Flat PVT collectors (Flat plate collectors).

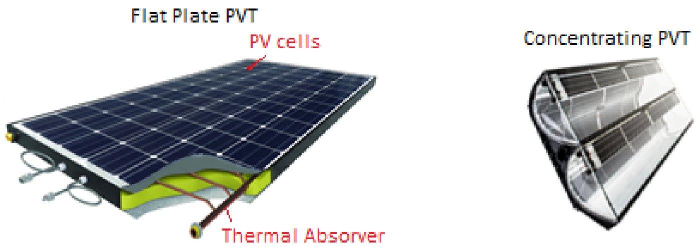

Figure 1 – Typical PVT panels (based on [2])

Regarding solar thermal collectors (ST), the cooling method can be divided as [2,6] passive cooling (if no additional power is required when extracting heat from the PV module) and active cooling (if additional power is required when extracting heat from the PV module). Even though active systems consume power, the greater cooling efficiency can compensate the additional power consumption, in the cases of domestic hot water heating.

The choice of the cooling method depends on several factors such as climate conditions, type of PV technology, the system's geometry and purpose that is, for instance, heating domestic water or control the temperature of a building's section. The water-cooling method has been widely adopted because of its ability to augment heat recovery.

These technologies generally have a bit lower thermal efficiency than thermal collectors, essentially due to four factors [2,6]: - A fraction of the incident solar radiation is directly converted into electricity by the PV cells; - The absorption coefficient of the PV surface is lower than that of a thermal collector leading to several losses by reflection; - The PV surface is not a selective emitter, resulting in high thermal losses due to radiation; - The thermal resistance increases due to the addition of successive layers of material leading to a lower heat transfer coefficient.

3. PVT SYSTEM VIABILITY AND CHALLENGES

Thermal efficiency of a PVT system proves to be a bit lower than that of a conventional T collector since PV cells cannot withstand such high temperatures. Based on the values associated with the system performances (PVT and PV+T combination), PVT energy generation can be higher than energy generation of a PV+T combination [2,6,7], as Fig. 2 illustrates.

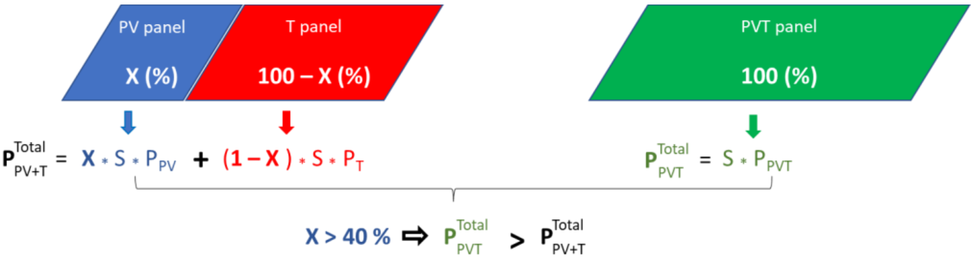

Figure 2 – Comparison of energy generation by PVT and by the combination PV+T (based on [7]).

Thus, Fig. 2 shows that if in the case of the PV deployment area X is higher than 40% of the full area available S then PVT energy generation is higher than energy generation of a PV+T combination.
Following the same approach, the costs with the PVT system are lower than with PV+T if in this case PV deployment area X is higher than 60% [7], in accordance with Fig. 3.

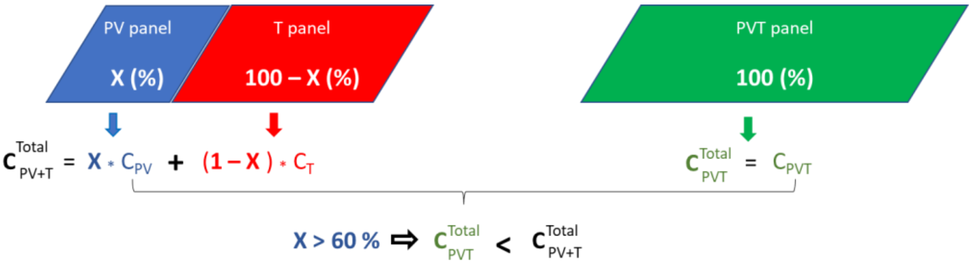

Figure 3 – Comparison of costs between PVT and the combination PV+T (based on [7]).

In this sense, the installation of PVT systems becomes technically and economically feasible whenever the implementation area corresponds to at least 60% of PV.
PVT technology faces some challenges that it must overcome, starting with (1) decreasing the price of the PVT collector and (2) increasing the thermal efficiency of the system to pave the way for (3) making PVT more popular, (4) placing in large roof areas could be preferable separate systems (PV+T), (5) there are not yet many certified hybrid panels on the market and (6) timing to launch a new technology to harness renewable energy.
In fact, these challenges should be seen as opportunities for PVT uptake [5,7].

4. LEGAL FACE AND BENEFITS OF SOLAR ENERGY IN EUROPEAN COUNTRIES

This chapter presents the most relevant aspects of the benefits and the legal face regarding solar energy in various European countries, with a view to its applicability to PVT systems. The countries covered in this chapter were studied as part of the PowerUp MyHouse project, and are EU countries (Portugal, Spain, France, Belgium, Italy, Greece, Germany, Netherlands, Denmark, Sweden, Lithuania, and non-EU countries (UK and Turkey).

EU countries:

To legislate on this matter, the governments of the European Union Countries use as background the Directive 2009/28/EC and Directive 2018/844/EU [3,4]. Directive 2009/28/EC establishes the existence of a National Action Plan for Renewable Energies (NAPRE). Each MS had to deliver the NAPRE to the European Commission, by 30 July

2010, in which national targets are defined for the shares of energy from renewable sources in 2020, as well as how the sectoral measures are going to be implemented to meet the outlined objectives.
In this sense, there were community guidelines that were published, and the MS transposed into national legislation. Regarding Energy Requirements and Performance of Buildings, it is important to highlight the Energy Performance of Buildings Directive; Directive 2010/31/EU of May 19, 2010, and constant amendments to Directive 2018/844/EU of May 30, 2018.
EU legislation aims to achieve for all new buildings an almost zero energy performance (nZEB - near Zero Energy Building) and a Long-Term Strategy for the Renovation of Buildings should be prepared to promote the renovation of the housing stock so that all buildings are transformed into buildings nZEB until the year 2050 [4]. For this purpose, regulatory instruments can be divided into three major areas: incentives based on production, incentives based on investment and incentives based on the legal framework. Production-based incentives are those based on the amount of energy produced. The main instruments are the minimum Feed-in tariff, production tax credits and the quota system. These instruments come bundled with a set of parameters that complement the main systems. On the other hand, investment-based incentives are intended to remunerate investors for their initial investment and can be, for example, tax incentives, tax exemptions, bank guarantees or accelerated depreciation. Finally, the third area encompasses the legal framework regarding non-monetary incentives, such as the type of regulator or the way projects are approved.
Tax incentives have been applied in several MS of the EU as a specific set of regulatory policy to encourage the production of renewable energy, which has been used to increase the production of renewable energy and, thus, reduce the effect of greenhouse gases [1].
Direct tax incentive systems are those that make it possible to reduce investment costs in renewable energy production, through exemption from taxes on individuals or taxes on companies. There are three types of taxes in the category of direct tax incentives [1]: personal income taxes, corporate taxes and property taxes:

- Private income tax, this type of incentive is used in some MS: Belgium and France;
- Corporate tax, this type of incentive is used in Belgium and Greece and has also been used in Spain. In Belgium and Greece there is an exemption from part of the expenditure on renewable energy production systems;
- Property Taxes. In Spain, Italy and Lithuania there is a local property tax. The underlying tax incentive is to reduce the tax paid by property owners who install renewable energy production systems in their properties. However, there are limits to these deductions. For example, in Italy the reduction only applies to properties that are the first residence of a family.

Indirect tax incentive systems are those that focus on energy production (not on investments) and include [1]:

- Value Added Tax (VAT), being a common tax within the EU, the incentive based on this instrument is related to the reduction of VAT on transactions involving the production of renewable energy. It is used in Portugal, France, Italy, Sweden and Denmark, being, in all cases, supported by the State. For example, in Portugal, the purchase of domestic renewable energy production systems is subject to an intermediate VAT rate.
- Exemption from excise taxes: this incentive is used in the promotion of renewable electricity through the special tax exemption since the use of this type of energy does not harm the environment. This type of incentive is used in Germany, Denmark, Lithuania, Netherlands and Sweden.

Generally, in EU countries there is no legislation that specifically addresses the PVT technology. The existing legislation on RES is separated into two different diplomas. One of them concerns the production of electrical energy (RES-E) and the other the heating of water (RES-H). At the microgeneration level, these diplomas can cover PVT systems [1], as is the case in France. So, in France the specific legislation from PV and T systems embraces PVT with the certification for Europe IEC (as Dualsun SolarKeymark PVT panel). Thus, by extension PVT technology enjoy the same incentive condition than PV and T, as it can accumulate condition of both systems. In Sweden, the regulations are mostly related to electricity production. For instance, the tax reduction is for the produced electricity (sold to the grid). And the so-called Green technique subventions (in form of tax reduction) of 15% for total cost of investment and installation of solar collectors is valid for PVTs if at least 20% of the system's total production provide electricity. In Germany, one PV subsidy scheme also includes PVT systems for all applications and is limited to grid connected systems only. In this scheme, the feed-in tariff is 114.7 €/MWh. For all applications such as source for heat pumps and self-consumption of electrical energy, or as ST system, only one specific PVT subsidy scheme is available in Germany in compliance with Solar Keymark. In this specific PVT subsidy scheme, the subsidy is 30% of overall costs (in case of using as ST) and 35% in combination with more renewables [1].

Non-EU countries:

In the United Kingdom RES-E are supported through a feed-in tariff, Contracts for Difference scheme and tax regulation mechanism. The Renewable Heat Incentive (RHI) is the main instrument for funding RES-H sources in the

UK by supporting RES-H installations with a fixed amount per kWth produced. The scheme consists of two parts: The Non-Domestic RHI (UK) and the Domestic RHI [1]. While the Non-Domestic RHI provides payments to industry, businesses and public sector organizations, is the Domestic RHI open to homeowners, private landlords, social landlords and self-builders. Generally, all technologies used in the generation of electricity and for heat generation from RES are eligible. However, domestic RHI does not support hybrid solar collectors PVT [1].
There are no incentive mechanisms and administrative regulations for direct PVT applications in Turkey [1]. However, different incentives are offered for applications for solar assisted electricity generation and applications for solar assisted hot water production. Until now, a clear incentive policy has not been implemented in Turkey for the dissemination of solar collector applications. Regarding RES-E a fixed tariff guarantee has been applied in Turkey. The duration of the relevant fixed tariff is defined as 10 years. Turkey has a strategic action plan regarding energy, in which is stated an increasing use of renewable energy [1].

5. CONCLUSION

The PVT technology is still very recent in commercial terms, so the existing legislation does not suitable or does not explicitly contemplate at all this type of system. Furthermore, there are not many references about legislation applicable to PVT technology. Thus, given the scarce information on the legal framework for PVT systems, this paper addresses this issue essentially at the level of RES systems to produce both electricity and heating, which are widely disseminated. The existing support and incentives, both for RES-E and for RES-H, in the different countries are significantly different both in terms of amounts and in terms of the diversity of financial mechanisms. On the other hand, in some cases there is the possibility that PVT systems are covered by the same supports as one or even both RES-E and RES-H systems. Economic and social premises are different in various European countries so that various funding levels, e.g. regional, municipal, and national, must be considered. Therefore, the subsidy situation is not easy to compare by numbers.
The next developments and opportunities in the renewable energy sector depend heavily on renewable energy development plans linked to the objective of reducing greenhouse gas emissions and the fulfillment of the commitments assumed under the Paris Agreement. These renewable energy development plans are governed in EU by two main regulations: The EU Winter Package, i.e. Clean energy for all Europeans and the Integrated National Energy and Climate Change Plan.
PVT can contribute for those low carbon solutions with its diurnal features of heating during the day and cooling during the night. As such, it is important for legislation and incentive schemes to be more comprehensive and clearer about these emerging viable technologies.

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