PANEVĖŽIO KOLEGIJA ISSN 2029-1280, eISSN 2669-0071. Taikomieji tyrimai studijose ir praktikoje – Applied Research in Studies and Practice, 2022, 18.

PVT Training Module for Vocational Secondary Education: A final version

Simon Furbo[a], Bengt Perers[a], Janne Dragsted[a], João Gomes[b], Sahand Hosouli[b], Mário Gomes[c], Paulo Coelho[c], Hasan Yıldızhan[d], Alper Bozkurt[d], Ercan Zengin[e], Mehmet Emin Dinçkurt[e], Diogo Cabral[f], Abolfazl Hayati[f], Evaldas Sapeliauskas[g], Remigijus Kaliasas[g]

[a]Department of Civil Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark
[b]MG Sustainable Engineering AB, Uppsala, Sweden
[c]Smart Cities Research Center (Ci2), Polytechnic Institute of Tomar, Tomar, Portugal
[d]Adana Alparslan Turkes Science and Technology University, Adana, Turkey
[e]Kurttepe Şehit Ali Öztaş Mesleki ve Teknik Anadolu Lisesi, Adana, Turkey
[f]University of Gävle, Gävle, Sweden
[g]Panevezys University of Applied Sciences, Panevėžys, Lithuania

Abstract. Within the project PowerUp MyHouse (Project No: 2020-1-TR01-KA202-093467) partners from Turkey, Portugal, Sweden, Lithuania, and Denmark cooperate on preparation of teaching materials on PVT systems. The project aims to develop the know-how about PV/T systems in design aspects by comparing different climate conditions and to increase the vocational skills and knowledge on PV/T systems of renewable energy vocational teachers/students. This document summarizes all stages of the project and the final conclusions of all participants.

Keywords: solar energy, PVT system, PVT training module, Renewable energy technologies

INTRODUCTION

The need for the energy increases approx. 4-5 % every year, on the other hand the reserve of the fossil fuel decreases much rapidly. The best optimist scenario says that the biggest part of the oil reserves will be finished in next 50 years. It is same for the gas and coal reserves. Besides global warming is threatening the basic life resources which are necessary for all livings to continue their lives on earth. Because of this, humanity must direct to the renewable energy sources before waiting till the end of the fossil fuel reserves. Based on REN21's report (Renewables 2022 global status report), modern renewables energy contributed 12.6% to humans' global energy consumption.

The sun is the most powerful source of renewable energy on Earth. However, at present, solar energy, as well as biomass, ocean, and wind energy, only make up 2.8% of total energy. On the other hand, the solar energy systems are growing and chancing every day. One of the great developments in this area is Photovoltaic thermal hybrid solar collectors, also known as hybrid PV/T (PVT).

The PVT technology connects solar PV and solar thermal in the same PVT panel. The panel consist both of PV cells and an absorber in good thermal contact with the PV cells. PVT panels can produce electricity, heating, and cooling. The PVT technology offers several potential advantages: The efficiency of the PV part will increase if we cool the PV panel with air or liquid through an absorber. Using PVT panels can save on panel materials as two technologies are used in the same area. Also, when installing PVT panels on building roofs and facades, construction materials can be saved, and the usable area of the roof is better utilized than using PV panels and solar collectors separately. In addition, the sealing technology of PVT panels is the same as that of PV panels. And, since PVT panels operate at a lower temperature than PV panels, PVT panels are expected to have a longer service life than PV panels. The PVT economy is still today difficult to calculate precisely, based on market prices and existing installations, as it is an early market where costs always are much higher than in a mass market. The potential economic advantages are though large, compared to separate PV or solar heating systems, as the same mounting structure, installation work and almost the same module design are used.

There are also disadvantages for PVT system: It is still a new technology in the field of solar energy in some less-developed European countries and for many applications the optimal designs of the PVT systems have not been elucidated. For example, in these countries, photovoltaic and solar thermal technologies are used separately, and PV/T technology is not used. This situation is due to the lack of knowledge/dissemination and practical results related to PV/T technology. In order for the situation to improve, it is necessary (Kramer et al., 2020):

- Targeted dissemination of best practices to vendors, industry and the general public;
- Work with the Solar Energy Association on long-term support policies;
- Technology improvement, price reduction. To use cheaper materials in PVT production.

© 2022 Panevėžio kolegija

The popularization of PVT technologies must first of all start with the youth, so our project aims were to develop the know-how about PV/T systems in design aspects by comparing different climate conditions and to increase the vocational skills and knowledge of PV/T for renewable energy vocational teachers and students. When preparing materials for vocational education teachers/students, the project was divided into several stages:

PVT technology research + Legal face of PVT+ Guidebook on PVT + Experiment = Learning module: a pilot application + Tested = Learning module: final version

BEST PRACTICES FOR PVT TECHNOLOGY

Although PVT collectors have emerged recently, they have been improved every year and now PVT collectors can be classified according to various characteristics (Diwania et al., 2019, Evangelisti et al., 2019).

PVT panels can be categorized by PV cells or solar panels. The most common element used in PV panels is silicon, the most popular of which are monocrystalline silicon (mono c-Si) and polycrystalline silicon (poly c-Si) or multilayer junctions. It should be noted that monocrystalline silicon has a higher efficiency (about 20%) than polycrystalline (15%), so a PV panel with mono c-Si of the same area generates more power than poly c-Si (Herez et al., 2020). PVT panels can also be divided depending on the type of solar collector, working fluid used, upper glazing, and other materials used in these panels, Fig. 1.

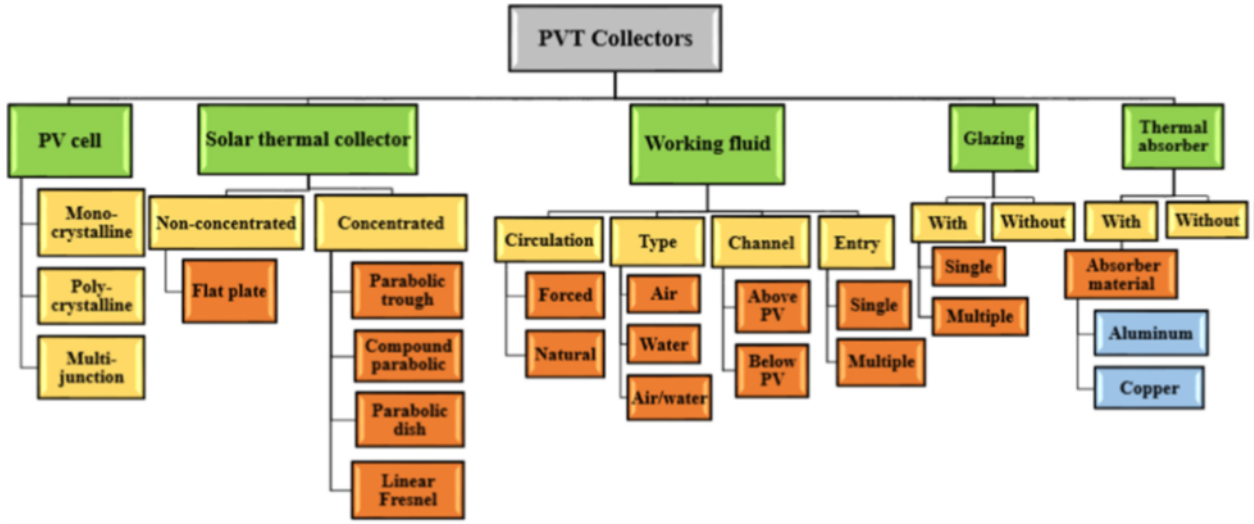

Figure 1. **Classification of PVT solar collectors** (Herez et al., 2020)

Depending on how the PVT modules are assembled thermal, electrical, and total efficiencies may be in the range 35-75%, 7-20% and 36-85% respectively (Herez et al., 2020). PVT systems can be used for many different applications and many different PVT system designs are possible.

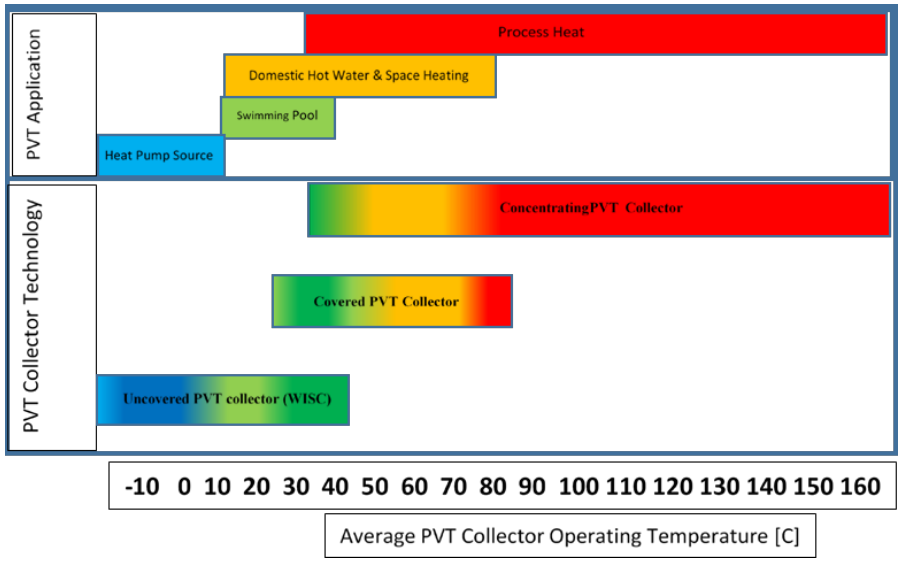

Figure 2. **PVT technology and applications for different temperature levels** (Lämmle et al, 2020)

Figure 2 gives an overview of PVT panel technologies and PVT applications for different temperature levels. Currently, approximately half of the installed PVT area of all operating PVT systems consists of air-cooled PVT panels (IEA 60 systems overview). Air-cooled PVT panels are suitable for buildings where air is used for heating. In these systems, air flow is the main player in reducing the temperature of the solar cells, thereby increasing the overall energy efficiency of the system. The thermal efficiency of such PVT panels is usually between 20% and 40% (Furbo et al., 2021).

The rest of the PVT systems are based on PVT panels with heat carriers, where the solar collector fluid cools the PV cells by circulating through the absorber. In simple PVT systems, solar collector fluid can be used very well to heat swimming pools.

To increase the overall efficiency of the heating system, PVT collectors can be used with a heat pump by installing a PVT panel on the cold side of the heat pump. A heat pump can achieve high efficiency using the heat produced by the PVT panel. These systems often use uncovered PVT panels, and systems with one or more thermal storage and electrical batteries can be intelligently controlled to optimize interaction with the power grid (Furbo et al., 2021).

LEGAL FACE OF PVT

The use of renewable energy sources (RES) is an important aspect supported worldwide, especially in Europe. States encourage the use of RES in money and in kind. These forms of promotion vary from country to country, region to region, and even depending on the technology used. For the technology used to establish itself in the markets it is necessary to have a legal framework to support it or at least not hinder it. Hybrid solar technology (PVT, i.e., photovoltaic (PV) and thermal (T)) is a new technology. Therefore, although PV and thermal energy are encouraged in Turkey, there are no incentives for PVT technology. The legal framework cannot keep pace with these ever-changing systems. The size of the support is very important for solar energy, especially for PVT (Gomes et al., 2022). From a commercial point of view, PVT technology is still very new, so there are no legal acts describing this type of system. In addition, the literature review showed that there is very little reference to the legislation applicable to PVT technology. Existing support and incentives for both PV panels and solar panels vary greatly from country to country, both in monetary amounts and in the variety of financial mechanisms. On the other hand, in some cases there is a possibility that PVT systems may be subject to the same forms of support as one or even both systems (photovoltaic (PV) and thermal (ST)). The economic and social well-being of households varies across European countries, and there are different levels of funding, e.g., regional, municipal, and national. Therefore, it is difficult to compare the level of support in different countries numerically. The Paris Agreement included commitments to reduce greenhouse gas emissions, and this could be greatly helped by further development of renewable energy. In the European Union, this development is governed 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 technology can contribute to greenhouse gas reduction solutions by using it for daily heating during the day and cooling at night. It is therefore important that legislation and incentive systems are more detailed and clearer about these promising new technologies (Gomes et al., 2022).

PVT TRAINING MODULE: A PILOT APPLICATION

PVT training module prepared by Adana Kurttepe Şehit Ali Öztaş Vocational and Technical Anatolian High School has been adapted by Lithuanian and Portuguese partners according to their own languages and conditions. In addition, PVT training was applied to at least 30 students and the results were evaluated. In the training module, firstly, theoretical information about Solar Energy, Photovoltaic Solar Technology and Photovoltaic Thermal Systems was given, then the experiment set was introduced, and explanations were made about the experiments that could be done in this experiment set. At the end, to determine the knowledge level of training participants about PV and PVT systems, the modules were evaluated with the help of tests.

PVT Training module was applied to two groups of 15 students from Adana Kurttepe Şehit Ali Öztaş Vocational and Technical Anatolian High School, Renewable Energy Technologies Field, 10th and 11th grade students. The pre-test before the training and the final-test after the training (Zengin et al., 2022) were applied to both groups. In this way, it was tried to determine the awareness and knowledge of the respondents about PVT systems before and after the training with the pre-test and final-test. On 28-29 April 2022, PVT training was carried out face-to-face theoretical and practical part by Panevėžys University of Applied Sciences

(PANKO-Panevezio Kolegija) in Lithuania. Pre-test and final-test were administered to the survey participants before and after the training, and 32 engineering students from different study programs such as Civil, Electrical and Automatic Equipment and Computer engineering participated in the training.

With the PVT training held in Portugal, Polytechnic Institute of Tomar (IPT) between 27 May and 15 June, 46 students from Electrical, Mechatronics and Mechanical engineering departments were trained, and pre-test and final-test were applied to the survey participants before and after the education. After the training module is applied, when the correct answer rates given by the students to the question of the area required for the PV/T system installation are examined. Below is a figure of the growth of students' knowledge level of individual questions about PV/T systems.

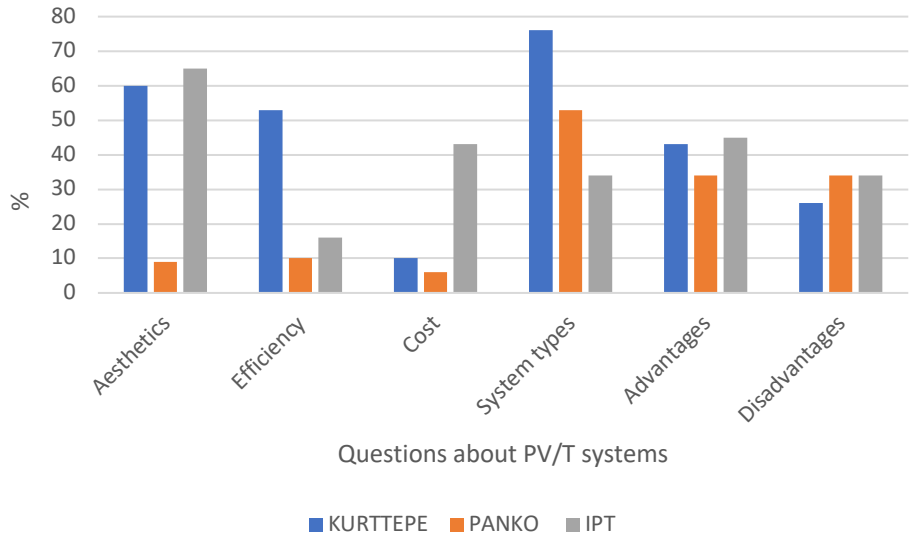

Figure 3. **Change in the growth of students' knowledge level in individual questions about PV/T systems** (Compiled by the authors)

In all three countries, the rate of correct answers after training increased compared to pre-training. This increase is 50% in Kurttepe MTAL; It was 10% in PANKO and 53% in IPT (Zengin et al., 2022). We can see that the level of knowledge of PANKO students about PV/T systems has increased slightly, this could be due to the fact that during the course of the project some respondents had already attended a lecture on PV/T, while in general PV/T systems are not included in the curriculum of the renewable energy subject (Zengin et al., 2022).

As a result of the implementation of the training module, it has been observed that the student‘s knowledge and skills on PV, PV/T Systems and Solar Energy Technologies increased. Likewise, feedback was received that the training was successful, that the training period was satisfied, and that this training would increase employability (Zengin et al., 2022).

PVT TRAINING MODULE: A FINAL VERSION

Considering the results of testing in three countries (Kurttepe MTAL, PANKO, IPT), the final version of the PVT Training Module for Vocational Secondary Education was prepared.

The content of the final product contained the following information:

- usage of PVTs;
- selection of the buildings;
- specifications of the PVTs;
- rules to be followed as work safety within the scope of using PVTs;
- manufacturing of PVTs;
- assembly of PVTs;
- cost/benefit rate;
- calculations;
- design and aesthetic;
- climate conditions;
- maintenance and sustainability, etc.

© 2022 Panevėžio kolegija

On 15-17 of Juni 2022, at Panevėžys University of Applied Sciences, Lithuania was applied theoretical part of the training on PV/T systems (O5 intellectual output) and conducted a survey. Pre-test and final-test (Zengin et al., 2022) were administered to the survey participants before and after the training, and 30 engineering students from different study programs such as Civil, Electrical and Automatic Equipment and Computer engineering participated in the training. The testing was realized as virtual presentation.

When the PV/T Education module is implemented at Panevėžys University of Applied Sciences, Lithuania (PANKO), the correct answer rates given by the respondents to the question of the space required for PV/T system installation ranged from 46.6% to 80%, and the correct answer rate to the question of aesthetic evaluation of PV/T system installations from 26.6% to 86.6%, the rate of correct answers to the question of evaluating the PV/T system efficiency from 66.6% to 83.3%, the rate of correct answers to the question of evaluating the cost of PV/T system installation from 33.3% to 90% has risen.

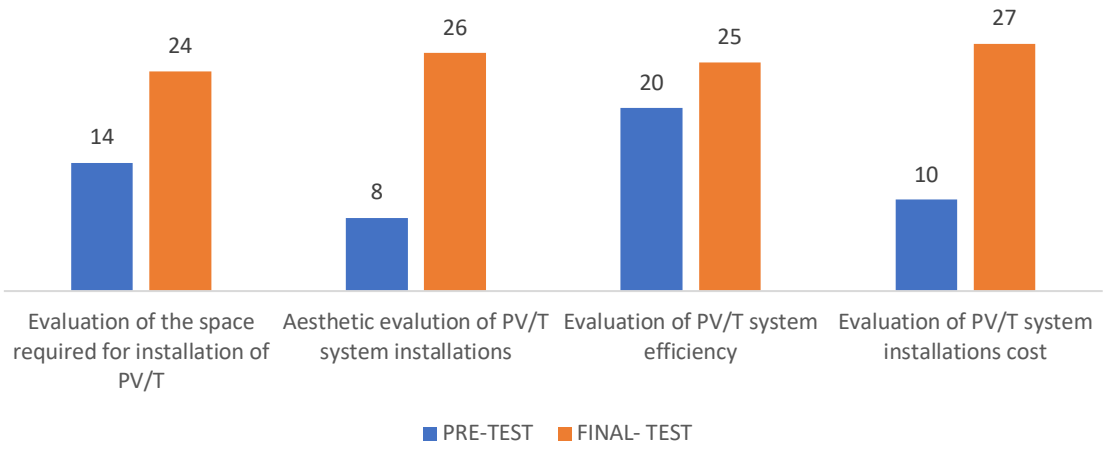

Figure 4. **The answers to the related questions in the pre-test and final-test** (Compiled by the authors)

While 43.75% of the respondents could not answer the question of what are the PV/T system types in the pre-test, 33% could give 1 correct answer. In the final-test, 100% of the students gave at least one correct answer.

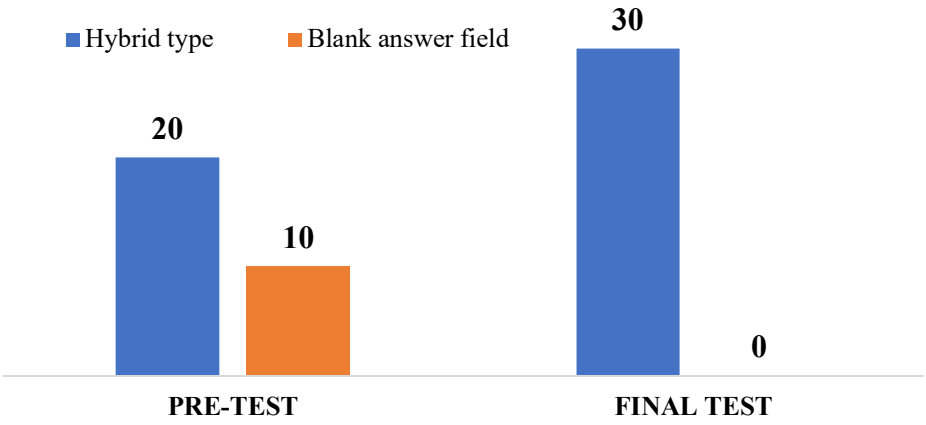

Figure 5. **Answers to the question of PV/T System types in the pre-test and final-test** (Compiled by the authors)

While 50% of the survey participants gave wrong answers to the question of what the advantages of PV/T systems in the pre-test are, 50% of them gave 1 or 2 correct answers. In the final-test, 100% of the students gave at least one correct answer.

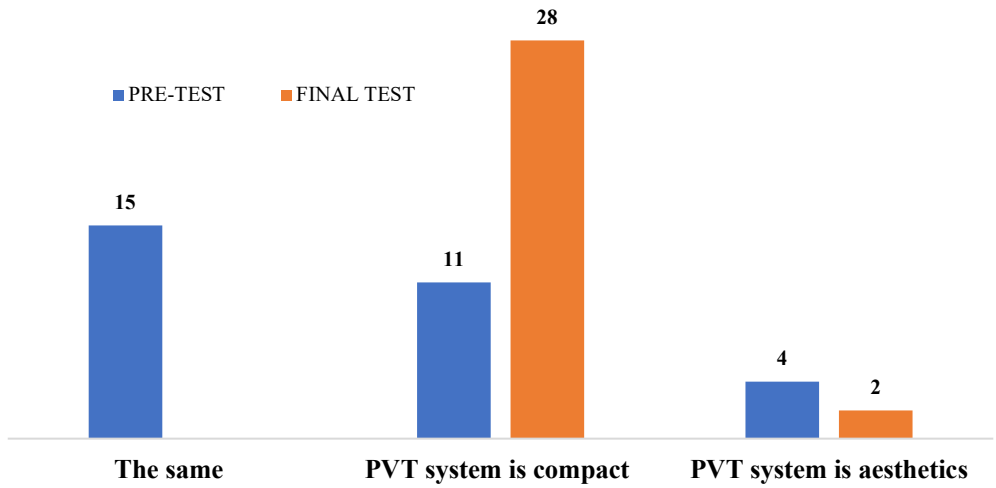

Figure 6. **The answers given in the pre-test and final-test to the question "Advantages of PV/T Systems"** (Compiled by the authors)

While 83,3% of the survey participants answered the question of what the disadvantages of PV/T systems as PVT system installation cost or installation difficulty in the pre-test are, 80% of the students answered the installation cost in the final-training test.

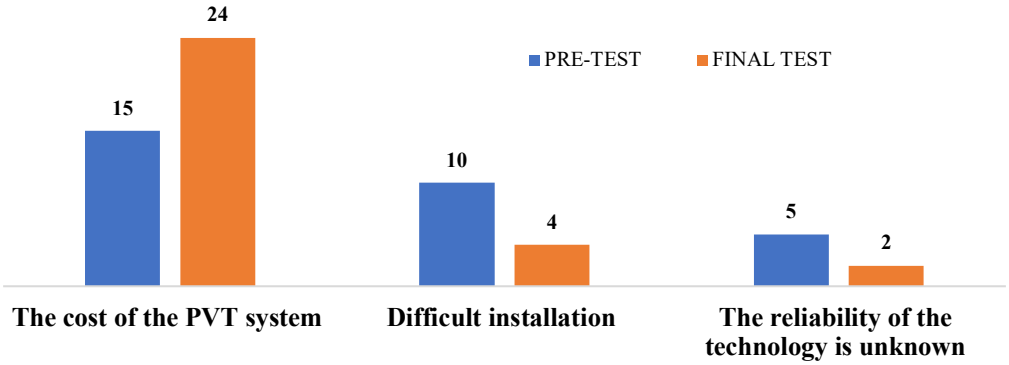

Figure 7. **The answers given in the pre-test and final-test to the question "Disadvantages of PV/T Systems"** (Compiled by the authors)

Below is a comparison of the pilot application and the final version testing. The test results of the final version match or are slightly better than the pilot application.

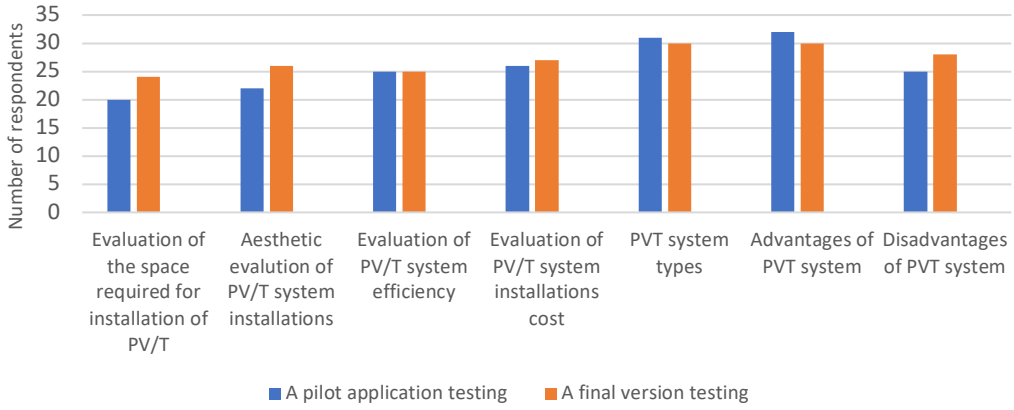

Figure 8. **Comparison of the pilot application and the final version testing** (Compiled by the authors)

This shows that the improved final version is suitable for the study process. It should be reminded that the number of respondents in the pilot application was 32, and 30 in the final version.

CONCLUSIONS

Today, the PVT market is still weak and the companies in this field are not yet big enough, so any changes in regulations and support schemes are sensitive to the PVT market.

Since PVT panels are still not mass produced, they are relatively expensive. In addition, we still do not have international standards for PVT panels and PVT systems. PVT panels are much more complicated, time consuming and expensive to test than PV panels. The system design is often quite complex, making installation time-consuming and difficult.

Currently existing legal acts are not fully adapted to PVT type systems. The existing grant and incentive for both PV panels and solar collectors varies widely from country to country, both in amounts and in the variety of financial mechanisms.

PVT panels installation is more complex than PV panels, so the training of the PVT installer is very important.

Teaching material on PVT systems is not included in the renewable energy curriculum. Looking to the future, we believe that this module on PVT systems can be included in the renewable energy curriculum as one of the program topics.

ACKNOWLEDGMENTS

The authors are thankful for the support given by EU to the project PowerUp MyHouse, agreement number 2020-1-TR01-KA202-093467 within the programme Erasmus+ Strategic Partnerships for vocational education and training.

We also thank all the support given by the project collaborators Jovita Kaziukonytė, Conceição Catroga, Emine Isildak and Yunus Çelik.

REFERENCES

Renewables 2022 global status report. https://www.ren21.net/wp-content/uploads/2019/05/GSR2022_Full_Report.pdf

Kramer, K., Herrando M., Brottier L., Ryan G., Zenhausern D., Sifnaios I., Pellegrini M. (2020). *PVT Collectors and systems. Technology position paper.* IEA SHC Task 60.

Diwania, S., Agrawal, S., Siddiqui, A.S., Singh, S. (2019). *Photovoltaic–thermal (PV/T) technology: a comprehensive review on applications and its advancement.* Int. J. Energy Environ. Eng. https://doi.org/10.1007/s40095-019-00327-y.

Evangelisti, L., De Lieto Vollaro, R., Asdrubali, F. (2019). *Latest advances on solar thermal collectors: A comprehensive review.* Renew. Sustain. Energy Rev. 114, 109318. https://doi.org/10.1016/j.rser.2019.109318.

Herez, A., Hage, H., Lemenand, T., Ramadan, M., Khaled, M. (2020). *Review on photovoltaic/thermal hybrid solar collectors: Classifications, applications and new systems.* Sol. Energy, 207, 1321–1347. https://doi.org/10.1016/j.solener.2020.07.062

Lämmle, M., Herrando, M., Ryan, G. (2020). *Basic concepts of PVT collector technologies, applications and markets.* Technical Report D.5. IEA SHC Task 60.

IEA 60 systems overview: https://task60.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task60-A1-Existing-PVT-Systems-and-Solutions.pdf

Furbo S., Perers B., Dragsted J., Gomes J., Gomes M., Coelho P., Yıldızhan H., Yilmaz I., Aksay B, Bozkurt A., Cabral D., Hosouli S., Hayati A., Kaziukonytė J., Sapeliauskas E., Kaliasas R. (2021). *Best practices for PVT technology*. In: ISES SWC 2021, 25-29 October 2021.

Gomes, M., Coelho, P., Yıldızhan, H., Bozkurt, A., Hayati, A., Cabral, D., Furbo, S., Perers, B., Dragsted, J., Hosouli, S., Gomes, J., Sapeliauskas, E., Kaliasas, R. (2022). *Highlights of Legal Face of PVT Systems in European Countries.* 10. Eur. Conf. Ren. Energy Sys. 07-09 May 2022, Istanbul, Turkey.

Zengin E., Dinçkurt, M.E., Yıldızhan, H., Gomes, M., Coelho, P., Kaliasas, R., Kaziukonytė, J. (2022). *PVT Training Module for Vocational Secondary Education: A Pilot Application.* Output O4 deliverable report. EU Project PowerUp MyHouse, Kurttepe, Adana.