www.insightcore.com

Journal of Buildings and Sustainability

2018
Vol. 1
No. 2

Review of sustainable energy technologies used in buildings in the Mediterranean basin

John Vourdoubas[a1]

[a]Mediterranean Agronomic Institute of Chania, Crete, Greece

A B S T R A C T

Reduction of energy consumption, fossil fuels use and carbon emissions in buildings is of paramount importance for mitigation of climate change. Increased use of renewable energy technologies for energy generation in buildings can promote the goal of sustainable development. Use of various reliable and cost-effective sustainable energy technologies for energy generation in buildings in the Mediterranean region has been investigated. Technologies using renewable energies available in the region like solar energy, wind energy, solid biomass and low enthalpy geothermal energy have been examined. Additionally, heat pumps, co-generation of heat and power and waste heat re-use have been also considered. Most of them are used for heat generation in buildings. These technologies have been evaluated using various non-technical methods combined with technical and economic criteria. The most promising technologies obtaining the highest score in the evaluation are district heating systems, solar thermal systems with flat plate collectors, high efficiency heat pumps and solar-PV panels. They are already used successfully in buildings in Mediterranean countries. It has also been indicated that the creation of net zero energy buildings with net zero carbon emissions is a feasible and cost-effective option in the Mediterranean region. This can be achieved with the combined use of various sustainable energy technologies.

Keywords: buildings, carbon emissions, heat, Mediterranean, power, renewable energies, sustainability

1. Introduction

Current policies in various countries try to mitigate the global threat of climate change and to increase the use of renewable energies replacing fossil fuels. Technological improvements of renewable energy technologies have increased their reliability and their cost-effectiveness in heat and power generation. Buildings consume large amounts of energy during their operation, contributing significantly in carbon emissions and in the greenhouse effect. Use of various renewable energy technologies in them, for heat and power generation, is easier compared with their use in industry, agriculture and transportation. European directives force the new buildings, constructed after 2020, to be nearly zero energy buildings reducing their energy consumption and carbon emissions. At the same time the creation of net zero energy buildings with zero CO_2 emissions, due to energy use, comprises an interesting challenge. The Mediterranean basin has abundant renewable energy resources which could be used for heat and power generation covering a large part of the energy needs of the countries located in this geographical area.

1.1 *Solar thermal systems with flat plate collectors*

A study concerning the advantages and drawbacks of domestic solar heating systems in the UK has been implemented by Greening et al, 2014. The authors have compared solar thermal systems with gas boilers, electricity and heat pumps according to eleven (11) environmental criteria. They concluded that they have many environmental advantages but due to their poor efficiency and the need for a back-up system, their future development in the UK seems rather limited. A review on solar water heating systems has been presented by Vinubhai et al, 2014. The

[1] vourdoubas@maich.gr

authors stated that solar water heating is one of the most effective technologies to convert solar energy into thermal energy and it is already a well developed and commercialized technology. However, they concluded that there are opportunities for further improvements in the reliability and efficiency of those systems. A review on the characterization of building-integrated solar thermal systems has been presented by Aelenei et al, 2016. The authors stated that in the past the decision for installing a solar thermal system in a building was based on techno-economic evaluations. However, today the decision should be based on additional criteria including architectural integration, aesthetics, functional and environmental characteristics.

1.2 *Solar parabolic collectors*

Design of a solar parabolic dish with a Sterling engine has been presented by Hafez et al, 2016. The authors have studied, with simulation techniques, the influence of various design parameters on the performance of the system. Depending on the reflector material, the power efficiency of the solar parabolic dish has been estimated between 49.52% and 97.07%. Quintal et al, 2011 have reported on the use of parabolic trough solar collectors for air conditioning and hot water production in buildings in Portugal. The authors stated that a small size system (10 KW) combined with absorption technology can be roof-mounted in a building and it can provide both air conditioning and hot water to it. They have also estimated that the system is cost-effective, having a payback period of eight (8) years without governmental subsidies.

1.3 *Solar thermal cooling*

A case study for a solar cooling system in a public building in Rome, Italy has been presented by Grignaffini et al, 2012. The authors stated that during the summer the demand for electricity increases in Mediterranean countries due to cooling requirements in buildings. The use of solar thermal energy with absorption chillers for cooling is attractive since solar energy is abundant when cooling is needed. They estimated that the solar cooling system can reduce the cooling load in the building by 26.5%. A report on solar air conditioning has been published by International Energy Agency, 2011. According to that, solar absorption technology is at a critical stage. The technology has shown that significant energy savings are possible, and it has reached a level of early market deployment. However, the financial risks of using this technology are still too high. A review of solar cooling technologies for residential applications in Canada has been reported by Baldwin et al, 2012. The authors stated that the implementation of solar cooling systems could assist in reducing energy consumption for space cooling in buildings. They also stated that limited work has been conducted in the area of small-scale systems worldwide while most of the existing solar cooling applications are related with large buildings. The use of solar heating and cooling in buildings has been reported by Henning et al, 2012. The authors have presented a design study of a solar thermal system providing heat and cooling in a hotel located in Malta in the Mediterranean Sea. Their results indicated that the life cycle cost of a solar heating and cooling system was not higher than a conventional one while primary energy savings up to 80% can be obtained.

1.4 *Solar photovoltaic use*

An analysis of building-integrated solar photovoltaics (solar-PV) in the Mediterranean climate has been presented by Salem et al, 2015. The authors have conducted a literature review regarding building-integrated photovoltaics (BIPVs). They found that they can produce an adequate amount of energy while being at the same time part of the building envelope. The use of solar-PVs in buildings has been studied by Hayter et al, 2002. The authors have investigated the performance of solar-PVs integrated in three commercial buildings in the USA. They concluded that the use of PVs in buildings offers many benefits and their use should be a standard consideration when designing a building. A review of building-integrated PVs has been presented by Biyik et al, 2017. The authors have investigated and compared the use of BIPVs together with the use of BIPVs combined with thermal systems for covering both electric and thermal loads. They found that existing technologies could be improved by a) ventilating the solar panels for lowering their temperature and increasing their yield, and b) by using thin film technologies integrating better the solar panels into the building envelope.

1.5 *Wind turbine use*

Building-integrated wind turbines have been studied by Bobrova et al, 2015. The author stated that perhaps in the future the wind generator will become an integral part of the house. Then, she stated, the form, structure and volume of the building will depend on integrating wind generators to them. Urban wind turbine integration in buildings has been reported by Abohela et al, 2011. The authors stated that wind turbine integration in buildings should be studied by multi-disciplinary teams in the early stages of building development. They also mentioned that wind generator use should include their social acceptance as well, apart from economic, technical and environmental criteria. A new building-integrated wind turbine system utilizing the building skin has been proposed by Park et al, 2015. The authors have designed a wind generator which utilized increased wind speed, due to specific configuration of the building skin, to generate electricity achieving a power coefficient at 0.381. An introduction to the small wind turbine project has been presented by Forsyth, 1997. The author has described the effort made to improve small wind turbines (5-40 KW) in order to have high reliability and low maintenance. He stated that the cost of the electricity generated was at 0.6 $/KWh for average wind speeds at 5.5 m/s.

1.6 *Solid biomass use*

An economic assessment of biomass boiler plants in Italy has been presented by Carlini et al, 2013. The authors have assessed the economic viability of using biomass boiler plants in residential buildings in Viterbo, Italy. They stated that economic subsidies of the biomass heating systems by the Government has resulted in a low payback period for these energy investments in residential buildings. A review of biomass heating for UK homes and commercial applications has been reported by Dwyer et al, 2006. The author suggested that biomass heating of buildings should be studied in the early stages of building design to achieve maximum benefits. However, he mentioned that biomass heating should not be considered as a standard solution like oil or gas for heating buildings, but rather as a green initiative to them.

1.7 *High efficiency heat pumps*

A general review of ground-source heat pump (GSHP) systems for heating and cooling in buildings has been presented by Sarbu et al, 2014. The authors stated that GSHPs are suitable for heating and cooling in buildings, having high efficiencies and reduced CO2 emissions. The annual increase in their use in buildings is remarkable due to the fact that they are more effective than many traditional systems. An evaluation of GSHP systems for residential buildings in warm Mediterranean regions like Cyprus has been reported by Michopoulos et al, 2016. The authors have analyzed with appropriate software two buildings, a single- and a multi-family building for two cases. In the former, a GSHP was used while the latter used a traditional system. Their results indicated a lower primary energy use in both buildings and a lower cost in the multi-family building when the GSHP was used. CO2 emissions were higher with the use of the GSHP in the single-house building but lower in the multi-family building. A study on the energy performance of a GSHP in historical buildings in Italy has been reported by Pacchiega et al, 2017. The authors stated that refurbishment of historical buildings, due to their characteristics, presents various difficulties regarding the selection of the optimal energy system. They also stated that GSHPs consist of the best solution, for heating and cooling, among those analyzed in historical buildings.

1.8 *Co-generation of heat and power (CHP)*

Martinez et al, 2011 have reported on energy supply in buildings with micro-cogeneration and heat pumps. The authors stated that these efficient energy technologies are important regarding energy supply in buildings for achieving the goals of EU legislation. An evaluation of combined heat and power generation has been published by International Energy Agency, 2008. According to this report, penetration of CHP technology in buildings is rather limited due to various barriers. These include electricity grid generation interconnection regulations, lack of knowledge about CHP benefits and savings and lack of integrated urban heating and cooling supply planning.

1.9 *District heating systems using biomass*

The design of a biomass district heating system has been reported by Vallios et al, 2007. The authors have presented a detailed design methodology of such energy systems which offers the possibility for their technical and economic assessment since there is limited experience and only few applications in Southern Europe. A review on biomass use in the Swedish district heating systems has been presented by Ericsson et al, 2016. The authors stated that district heating satisfies about 60% of the heat demand in Swedish buildings while biomass alone accounts for about half of the heat supply. They concluded that biomass introduction and expansion was supported by national energy policy tools and local municipal initiatives. The use of biomass for district heating has been reported by Chatzistougianni et al, 2016. The authors stated that locally available biomass can support a small-scale district heating system of public buildings especially when taking into account energy audits, in-situ measurements and energy efficiency improvement measures.

1.10 *District heating with waste heat*

District heating using waste heat from thermal power-generating plants in the EU has been studied by Colmenar-Santos et al, 2016. The authors stated that thermal power plants in the EU reject a large amount of heat compared with the heat energy used in buildings. They also mentioned that about half of the installed capacity in the EU's conventional thermal power plants are located at an appropriate distance from cities and towns, allowing the use of the waste heat in district heating systems. Low temperature district heating for future energy systems has been reported by Schmidt et al, 2017. The authors stated that low temperature district heating can significantly contribute to a more efficient use of energy resources as well as better integration of renewable energies, like geothermal energy, solar energy and surplus heat, like industrial waste heat, to the building sector.

1.11 *Creation of net zero energy buildings with zero carbon emissions due to energy use*

A study on zero energy balance buildings in southern Italy has been presented by Ferrante et al, 2011. The authors stated that zero energy balance buildings can be achieved combining solar passive systems with solar and wind energy micro-generation. They concluded that zero energy balance and zero on-site CO2 emissions houses in the Mediterranean climate are easily accessible goals. A study of zero CO2 emissions residential buildings due to energy use located in Crete, Greece has been reported by Vourdoubas, 2016.The author indicates that the combination of solar thermal energy, solar-PV and solid biomass could cover all the energy needs of a building, zeroing its CO_2 emissions due to energy use. He also stated that the same result could be achieved in the building with the combined use of solar thermal energy, solar-PV and GSHPs.

The aims of the current work are:

a) To review the sustainable energy technologies which are currently used in buildings for providing heat, cooling and electricity in the Mediterranean basin,

b) To assess them with technical and non-technical criteria, and

c) To investigate if their combined use could result in the creation of a net zero energy building with zero carbon emissions due to operational energy use

2. Sustainable energy technologies for energy generation in buildings

Various sustainable energy technologies including renewable energies and high efficiency energy systems can be used for providing energy in buildings in the Mediterranean region. They can generate heat, cooling and electricity and their use depends on many parameters including, among others, their availability, the local climate conditions and their cost-effectiveness. Some of them are used broadly while others have limited applications. New innovative energy systems are also used experimentally, and they will probably be expanded and commercialized in the future. Solar energy is used in buildings for heat, cooling and electricity generation. Solar thermal systems with flat plate collectors have been used for many decades while co-generation systems with parabolic collectors have been recently developed without proving their cost-effectiveness so far. Solar-PV systems are broadly used today after a sharp decrease in their prices in the previous years. Solar cooling systems are only used in large buildings although this technology is very challenging in the Mediterranean region. Small wind turbines have limited applications mainly in off-grid buildings. Solid biomass burning is broadly used for heat generation, particularly in rural areas. Heat pumps are increasingly used for heating and cooling in buildings having many advantages including their high efficiencies. Co-generation of heat and power is mainly used in large buildings consuming mainly natural gas. Finally, district heating systems fuelled with either biomass or waste heat are used only when the fuels are available nearby the building's community. A list of various sustainable energy technologies which could be used for energy generation in buildings is presented in Table 1.

Table 1. Various sustainable energy technologies which can be used in buildings for generation of heat, cooling and electricity in the Mediterranean basin[1]

Technology	Space heating	Space cooling	Domestic hot water	Electricity
Solar thermal with flat plate collectors			+	
Solar thermal with parabolic collectors and Stirling engine	+		+	+
Solar thermal cooling		+		
Solar-PV				+
Wind energy				+
Solid biomass burning	+		+	
High efficiency heat pumps	+	+	+	
Co-generation of heat and power	+		+	+
District heating with solid biomass	+		+	
District heating with waste heat	+		+	
Total	6	2	7	4

[1]Source: Own estimations

Table 1 indicates that the most sustainable energy technologies can provide heat but only a few can provide cooling. The current use of sustainable energy technologies in buildings in the Mediterranean region is presented in Table 2.

Table 2. Current use of various sustainable energy technologies in buildings in the Mediterranean area [1]

Technology	Current use of the technology
Solar thermal with flat plate collectors	Yes, broadly
Solar thermal with parabolic collectors and Stirling engine	Experimentally, few commercial applications
Solar thermal with parabolic collectors and Stirling engine	Limited applications mainly in large buildings
Solar-PV	Yes, broadly
Wind energy	Limited applications mainly in off-grid buildings
Solid biomass burning	Yes, broadly
High efficiency heat pumps	Yes, broadly
Co-generation of heat and power	Limited applications mainly in large buildings
District heating with solid biomass	Limited applications
District heating with waste heat	Limited applications

[1]Source: Own estimations

The efficiency of various sustainable energy systems varies significantly since some technologies like solar-PV have low efficiency while others like GSHPs and cogeneration systems have high efficiencies. The efficiency of various technologies used in buildings is presented in Table 3.

Table 3. Efficiency of various sustainable energy technologies used in buildings in the Mediterranean area[1]

Technology	Efficiency (%)
Solar thermal with flat plate collectors	30-35
Solar thermal with parabolic collectors and Stirling engine	There are not enough reliable data
Solar thermal with parabolic collectors and Stirling engine	100-120
Solar-PV	15-18
Wind energy	15-18
Solid biomass burning	70-80
High efficiency heat pumps	250-350 (COP =2.5-3.5)
Co-generation of heat and power	75-85
District heating with solid biomass	70-80
District heating with waste heat	80-90

[1]Source: Own estimations

3. Assessment of various sustainable energy technologies used in buildings

Assessment of the above-mentioned renewable energy technologies has been made using technical and non-technical criteria. In the non-technical criteria are included the simplicity of the installation of the energy system, its accessibility, its ease of use from the end user and its social acceptance. Among the technical and economic criteria are included its cost-effectiveness, its ease of maintenance, its reliability and its efficiency. For each criterion a score between 1 (low) to 5 (high) is given. Scores for non-technical assessment and for technical and economic assessment are presented in Tables 4 and 5.

Table 4. Non-technical assessment of various sustainable energy technologies used in buildings in the Mediterranean area [1,2]

Technology	Simplicity of installation	Accessibility	Easy to use for the end user	Social acceptance	Total score
Solar thermal with flat plate collectors	5	4	5	5	19
Solar thermal with parabolic collectors and Stirling engine	1	2	2	4	9
Solar thermal cooling	2	2	4	4	12
Solar-PV	5	4	5	5	19
Wind energy	2	3	3	2	10
Solid biomass burning	4	4	4	4	16
High efficiency heat pumps	5	5	5	5	20
Co-generation of heat and power	4	3	4	4	15
District heating with solid biomass	5	5	5	5	20
District heating with waste heat	5	5	5	5	20

[1]Score: 1=low to 5=high
[2]Source: Own estimations

Table 5. Technical and economic assessment of various sustainable energy technologies used in buildings in the Mediterranean area [1,2]

Technology	Cost effectiveness	Easy to maintain	Reliability	Efficiency	Total score
Solar thermal with flat plate collectors	4	5	5	4	18
Solar thermal with parabolic collectors and Stirling engine	2	1	3	-	6
Solar thermal cooling	2	2	3	5	12
Solar-PV	4	5	5	2	16
Wind energy	2	2	4	2	10
Solid biomass burning	5	4	5	5	19
High efficiency heat pumps	4	4	5	5	18
Co-generation of heat and power	4	4	5	5	18
District heating with solid biomass	5	5	5	5	20
District heating with waste heat	5	5	5	5	20

[1]Score: 1=low to 5=high
[2]Source: Own estimations

The total score and the ranking of the sustainable energy technologies are presented in Table 6. The best scores are achieved in the district heating systems using either solid biomass or waste heat since the district heating operator is providing the heat into the buildings which are the end users while the heat price is relatively low.

Table 6. Ranking of the energy technologies according to the score given[1]

Technology	Score for the non-technical criteria	Score for the technical and economic criteria	Total score	Ranking
Solar thermal with flat plate collectors	19	18	37	3rd
Solar thermal with parabolic collectors and Stirling engine	9	6	15	8th
Solar thermal cooling	12	12	24	6th
Solar-PV	19	16	35	4th
Wind energy	10	10	20	7th
Solid biomass burning	16	19	35	4th
High efficiency heat pumps	20	18	38	2nd
Co-generation of heat and power	15	18	33	5th
District heating with solid biomass	20	20	40	1st
District heating with waste heat	20	20	40	1st

[1]Source: Own estimations

4. Creation of net-zero energy buildings in the Mediterranean basin

Creation of buildings with net zero energy balance and zero CO_2 emissions due to energy use consists of a great challenge nowadays for mitigating climate change. Reduction of energy consumption in buildings with the use of various energy-saving techniques combined with in-situ energy generation from benign energy sources could achieve the above-mentioned goal. Various studies implemented so far indicate that this is feasible due to technology improvements and the cost reduction of sustainable energy technologies. Various renewable energies which, combined, can provide all the energy required in a grid-connected building are presented in Table 7. Solar thermal energy can provide domestic hot water and solar-PV energy all the electricity required for lighting and operation of various equipment with the net-metering regulations. Solid biomass can provide space heating while GSHPs can provide space heating and cooling. Apart from the renewable energies presented in Table 7, combined use of different renewable energy technologies could achieve the same goal. As an example, use of district heating systems fuelled with solid biomass or waste heat can provide space heating and domestic hot water, heat pumps can provide space cooling and solar-PV panels can provide all the electricity required in the building. All these technologies are mature, reliable, well-proven and cost-effective. The renewable energies mentioned are abundant in the Mediterranean region except for the limited availability of solid biomass in southern Mediterranean countries.

Table 7. Renewable energy technologies which can provide all the energy required in a building [1,2]

Renewable energy	Combined use of solar thermal, solar-PV and solid biomass	Combined use of solar thermal, solar-PV and GSHPs
Solar thermal	Domestic hot water	Domestic hot water
Solar-PV	Electricity generation	Electricity generation
Solid biomass	Space heating	
Low enthalpy geothermal energy		Space heating and cooling

[1] Grid connected building with net-metering regulations
[2]Source: Vourdoubas, 2016

5. Discussion

Renewable energy technologies which can be used for heat, cooling and electricity generation like solar energy, wind energy, low enthalpy geothermal energy and solid biomass are abundant in many Mediterranean countries. Various mature and reliable renewable energy technologies can be used without any financial subsidy. Current EU regulations make it obligatory in the coming years for the construction of new nearly zero energy buildings while policies like the net-metering regulation promote the use of solar-PVs or cogeneration systems in buildings without economic subsidies. Biomass-fuelled district heating systems have very good performance, but they are limited in northern Mediterranean countries in areas with high availability of biomass resources. Solar thermal systems with parabolic collectors and Stirling engines have only recently penetrated the market and the evaluation of their performance will take some time. Energy transformation of existing buildings in order to reduce their energy consumption and their carbon footprint due to energy use could contribute to the mitigation of climate change while decreasing the dependence of various countries on imported fossil fuels. Solar energy is abundant in the Mediterranean region and the use of solar-PVs is currently promoted in many countries. According to Table 1, only two technologies are available for space cooling in buildings; however, only one is being used extensively today. Probably technological improvements in the near future will allow the creation of more reliable and cost-effective solar cooling systems which could be used in Mediterranean countries which have abundant solar irradiance. Increased use of sustainable energy technologies in buildings do not require financial subsidies but rather non-financial support and the removal of various barriers. These include appropriate training of engineers and building constructors concerning the use of renewable energies in buildings, involvement of the private sector and third party financing in energy investments in large public buildings and/or in social houses, better information for the consumers regarding the benefits of sustainable energies and the creation of a few public buildings with net zero energy consumption which could raise awareness among citizens and will demonstrate the use of benign energy sources in them.

6. Conclusions

Various mature, reliable and cost-effective renewable energies can be used for heat, cooling and power generation in buildings in the Mediterranean region. These include solar thermal energy with flat plate collectors, solar thermal energy with parabolic collectors, solar cooling, solar-PV energy, solid biomass burning, wind energy, high efficiency heat pumps, co-generation of heat and power and district heating systems using solid biomass or waste heat. Solar energy, low enthalpy geothermal heat and, at least in some countries, solid biomass are abundant in this geographical district. The majority of the above-mentioned renewable energy technologies are related with heat generation in buildings. Current policies and the legal framework in most Mediterranean countries support their use of energy generation in them. The efficiency of the sustainable energy technologies examined varies broadly between 15% to 350%. Various criteria have been used for the evaluation of the sustainable energy technologies. These include non-technical criteria like accessibility, social acceptance, simplicityof installation and ease of use for the end user. Additionally, technical and economic criteria include reliability, efficiency, ease of maintenance and cost-effectiveness. Assessment of the examined technologies used for energy generation in buildings in the Mediterranean area indicated that district heating systems, solar thermal systems with flat plate collectors, high efficiency heat pumps and solar-PV panels have the best performance. The combined use of various renewable energy technologies in buildings could result in net zero energy buildings and zero carbon emissions buildings in the Mediterranean region. These technologies are mature, reliable and cost-effective and they are already used separately in various buildings. Therefore, the creation of net zero energy buildings is currently feasible and cost-effective in the Mediterranean basin. Further work should be focused on the transformation of various public buildings in Mediterranean countries to net zero energy buildings with the combined use of the above-mentioned renewable energy technologies.

References

Abohela, I., Hamza, N. &Dudek, S. (2011). Urban wind turbines integration in the build form and environment, *in the Forum Ejournal 10*, June 2011, 23-39. Retrieved at 4/6/2918 from https://research.ncl.ac.uk/forum/v10i1/2_Islam.pdf

Aelenei, L., Smyth, M., Platzer, W., Norton, B., Kennedy, D., Kalogirou, S. & Maurer, Ch. (2016). Solar thermal systems- Towards a systematic characterization of building integration, *Energy Procedia*, *91*, 897-906. doi: 10.1016/j.egypro.2016.06.256

Baldwin, Ch. & Cruickshank, C.A. (2012). A review of solar cooling technologies for residential applications in Canada, *Energy Procedia*, *30*, 495-594.doi: 10.1016/j.egypro.2012.11.059

Biyik, E., Araz, M., Hepbasli, A., Shahrestani, M., Yao, R., Shao, L., Essah, E., Oliveira, C.A., Del Cano, T., Rico.E., Lechon, J.L., Andrade, L., Mendes, A. &Atli, Y.B. (2017).A key review of building integrated photovoltaic (BIPV) systems, *Engineering Science and Technology, an International Journal, 20,* 833-858.https://doi.org/10.1016/j.jestch.2017.01.009

Bobrova, D. (2015). Building-Integrated wind turbines in the aspect of Architectural shaping, *Procedia Engineering*, *117*, 404-410. doi: 10.1016/j.proeng.2015.08.185

Carlini, M., Castellucci, S., Cocchi, S., Allegrini, E. & Li, M. (2013). Italian residential buildings: Economic assessment for biomass boilers plants, *Mathematical Problems in Engineering,* Article 823851, http://dx.doi.org/10.1155/2013/823851

Chatzistougianni, N., Giagozoglou, E., Sentzas, K., katastergios, E., Tsiamitros, D., Stimoniaris, D., Stomoniaris, A. &Maropoulos, S. (2016). Biomass district heating methodology and pilot installations for public buildings groups, in *20th Innovative Manufacturing Engineering and Energy Conference,* doi:10.1088/1757-899X/161/1/012083

Colmenar-Santos, A., Rosales-Asensio, E., Borge-Diez, D. &Blanes-Peiro, J.J. (2016). District heating and co-generation in the EU-28: Current situation, potential and proposed energy strategy for its generalization, Renewable and Sustainable *Energy Reviews*, *62*, 621-639, http://dx.doi.org/10.1016/j.rser.2016.05.004

Dwyer, T. (2006). A review of biomass heating for UK homes and commercial applications, *International Journal of Low Carbon Technologies, 1*(4), 329-335. https://doi.org/10.1093/ijlct/1.4.329

Ericsson, K. & Werner, S. (2016). The introduction and expansion of biomass use in Swedish district heating systems, *Biomass and Bioenergy*, *94*, 57-65. http://dx.doi.org/10.1016/j.biombioe.2016.08.011

Ferrante, A. &Cascella, M.T. (2011). Zero energy balance and zero on-site CO_2 emission housing development in Mediterranean climate, *Energy and Buildings, 43,* 2002-2010. doi:10.1016/j.enbuild.2011.04.008

Forsyth, T.L. (1997). An introduction to the small wind turbine project, presented at Wind-power ’97, Austin, Texas, USA, June 15-18,1997, National renewable energy laboratory

Greening, B. &Azapagic, A. (2014). Domestic solar thermal water heating: A sustainable option for the UK? , *Renewable Energy*, *63*, 23-36. http://dx.doi.org/10.1016/j.renene.2013.07.048

Grignaffini, S. & Romagna, M. (2012). Solar cooling: a case study, *WIT transactions on ecology and the environment, Eco-Architecture IV, 165,* 399-410. doi:10.2495/ARC120351

Hafez, A.Z., Soliman, A., El-Metwally,K.A. & Ismail, I.M. (2016). Solar parabolic disc Stirling engine system design, simulation and thermal analysis, *Energy Conversion and Management, 126*, 60-75. DOI: 10.1016/j.enconman.2016.07.067

Hayter, S., Torcellini, P. &Deru, M. (2002). Photovoltaics for buildings: New applications and lessons learnt, American council for an energy efficient economy, *Summer study on energy efficiency in buildings*, Pacific Grove, California, USA, August 18023. 2002. Retrieved at 4/6/2018 from https://www.nrel.gov/docs/fy02osti/32158.pdf

Henning, H.M. & Doll, J. (2012). Solar systems for heating and cooling of buildings, *Energy Procedia*, *30*, 633-653. doi: 10.1016/j.egypro.2012.11.073

International Energy Agency, Combined Heat and Power, Evaluating the benefits of greater global investments, France, 2008. Retrieved at 4/6/2018 from https://www.iea.org/publications/freepublications/publication/chp_report.pdf

International Energy Agency, Task 38, Solar air conditioning and refrigeration, Solar Cooling position paper, 2011. Retrieved at 4/6/2018 from https://nachhaltigwirtschaften.at/resources/iea_pdf/iea_shc_solar_cooling_position_paper.pdf

Martinez, M.G., Andrade, L.C., Bugallo, P.M.B. & Iglesias, M.B., Energy supply in buildings: heat pump and micro-cogeneration. In *World Renewable Energy Congress 2011*, 8-13 May 2011, Linkoping, Sweeden.

Michopoulos, A., Voulgari, V., Tsikaloudaki, A. &Zachariadis, Th. (2016). Evaluation of ground source heat pump systems for residential buildings in warm Mediterranean regions: the example of Cyprus, *Energy Efficiency*, *9*, 1421-1436. DOI 10.1007/s12053-016-9431-1

Pacchiega, C. &Fausti, P. (2017). A study on the energy performance of a ground source heat pump utilized in the refurbishment of an historical building: comparison of different designed options, *Energy Procedia*, *133*, 349-357, https://doi.org/10.1016/j.egypro.2017.09.360

Park, J., Jung, H.J., Lee, S.W. & Park, J. (2015). A new building integrated-wind turbine system utilizing the buildings, *Energies*, *8*, 11846-11870.doi:10.3390/en81011846

Quintal, E.S., Bernardo, H.S., Amaral, P.G. &Neves, L.D. (2011). Use of parabolic trough solar collectors for building air conditioning and domestic hot water production - A case study, *3RD International Youth Conference on Energetics*, July 2011, DOI: 10.13140/RG.2.1.2498.7683

Salem, T. &Kinab, E. (2015). Analysis of building-integrated photovoltaic systems: A case study of commercial buildings under Mediterranean climate, *Procedia Engineering*, *118*, 5380545. doi: 10.1016/j.proeng.2015.08.473

Sarbu, I. &Sebarchievici, C. (2014). General review of ground source heat pump systems for heating and cooling buildings, *Energy and Buildings*, *70*, 441-454, http://dx.doi.org/10.1016/j.enbuild.2013.11.068

Schmidt, D., Kallert, A., Blesl, M., Svendsen, S., Li, H., Nord, N. &Sipila, K. (2017).Low temperature district heating for future energy systems, *Energy Procedia*, *116*, 26-38.https://doi.org/10.1016/j.egypro.2017.05.052

Valios, I. &Tsoutsos, Th. (2007). Design of biomass district heating systems, *In 15th European Biomass Conference*, Berlin, Germany, 7-11 May 2007.

Vinubhai, T.S., Vishal, R.J. &Thakkar, K. (2014). A review: Solar water heating systems, in the *National conference on emerging Vista of technology in the 21st century*. DOI: 10.13140/2.1.1910.5281

Vourdoubas, J. (2016). Creation of zero CO_2 emission residential building due to energy use: A case study in Crete, Greece, *Journal of Civil Engineering and Architecture Research*, *3*(2), 1251-1259.