OVERVIEW OF COMBINED SOLAR THERMAL AND HEAT PUMP SYSTEMS

Technical Report 5.1.1

Austrian Institute of Technology

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Quality Assurance in solar thermal heating and cooling technology – keeping track with recent and upcoming developments

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1 Introduction

The combination of solar thermal and heat pump systems is not new [1-3]. Several companies offered system combinations which, in most cases, were operating in parallel delivering heat to a common storage tank. Different hydraulic schematics including one or more storages, pumps etc. were used. Although a number of research groups reported on systems with a more complex configuration, there were but a few known systems available on the market.

In recent years, however, quite a large number of solar thermal and heat pump systems (SHP systems) were marketed as packaged solutions for domestic applications (domestic hot water preparation and / or heating with an optional cooling function) by several companies in different European countries. These products feature a number of different configurations and control strategies. This enables them to interact in different ways, depending on the given operating conditions. An overview of the most common configurations can be found e.g. in [4] or [5]. This quite sudden market development was accompanied by lively research activities on that field – a tendency that is still on-going.

As stated in Technical Report 5.1.2 of Deliverable 5.1 [6], there are currently no test procedures for SHP systems available. This can have a negative impact on future market development of the technology. Nevertheless, some research groups are currently working on the development of such procedures, as described in Technical Report 5.1.4 [7] of Deliverable 5.1. These test procedures can be roughly divided into two main groups:

- procedures based on component tests under steady-state/transient operating conditions, parameter identification of components and/or subsystems and simulation of the whole system for defined, transient boundary conditions;
- procedures based on the laboratory measurement of the whole system or at least major system parts under different steady-state and/or transient operating conditions with possible emulation of system parts. The results are used for model parameterisation and/or extrapolation of the results for defined, transient boundary conditions (i.e. to obtain seasonal system performance or efficiency).

From the market point of view, it is very important to be able to cover all (or at least the most common) system components and system configurations (or operating modes) by the test procedures. This also includes the definition of different operating conditions for testing. In this context, it is important to obtain a good overview of the variety of the products on the market and their main characteristics and to try to classify the systems for future development of testing and rating methods.

A questionnaire covering the main aspects of possible interactions between the heat pump and the solar thermal subsystems, intended applications, component types and interaction with the environment was developed and distributed by the project partners in each of the participating countries within the project. The questionnaire is shown in Annex I. The filled questionnaires for all collected SHP systems were collated in separate Annex II to this document, which will not be publicly available.

Additionally, an agreement with IEA SHC Task 44 / HPP Annex 38 “Solar and Heat Pumps” was reached regarding information exchange, which included SHP system overview.

It should be mentioned, that the nomenclature used in Figure 1 of the questionnaire has been changed in the course of the project (see Figure 3).

2 Evaluation and categorisation of SHP systems

The survey included the following EU countries: Austria, Denmark, France, Germany, Greece, Italy, Portugal, Spain, Sweden and Switzerland[1]. 96 products from 65 companies were collected and evaluated. Figure 1 shows the distribution of companies and products by the country of origin.

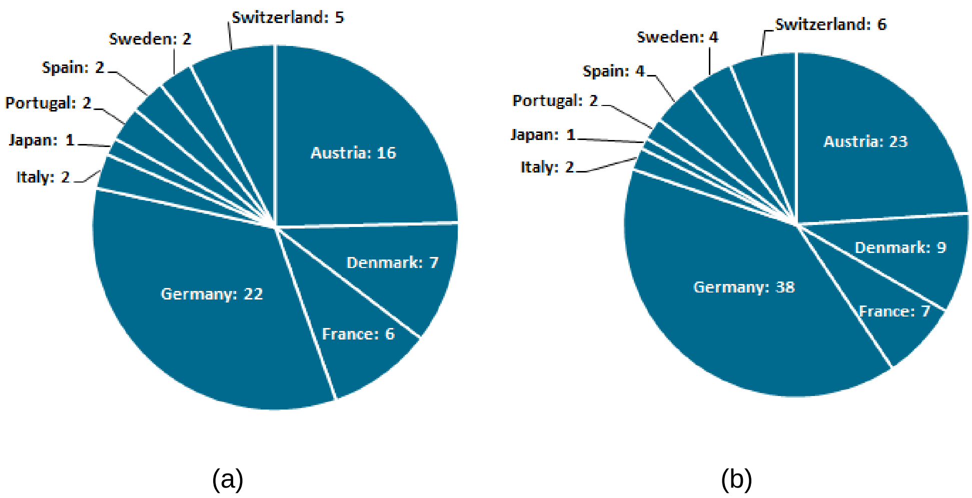

Figure 1: Distribution of companies (a) and products (b) by country

[1] In the course of the survey, one product from Japan was also found to be sold on the European markets and was included in the review.

The systems were analysed according to the following characteristics:

- intended application (heating, domestic hot water, cooling);
- general type of system configuration;
- possibility to operate in different operation modes;
- interaction between solar thermal and heat pump subsystems;
- type of collector;
- source of the heat pump.

Most of the systems were designed for combined heating and domestic hot water preparation, 81 %. Around 17 % of the products were used for domestic hot water only. Only 2 products form one company (2 %) were intended for heating only.

From all the systems covered by the survey, 21 % was designed also for cooling purposes. All systems designed from cooling were at the same time combined systems for heating and DHW preparation. Around half of these systems (43 %) were ground-coupled and capable of free cooling.

An overview is shown in Figure 2.

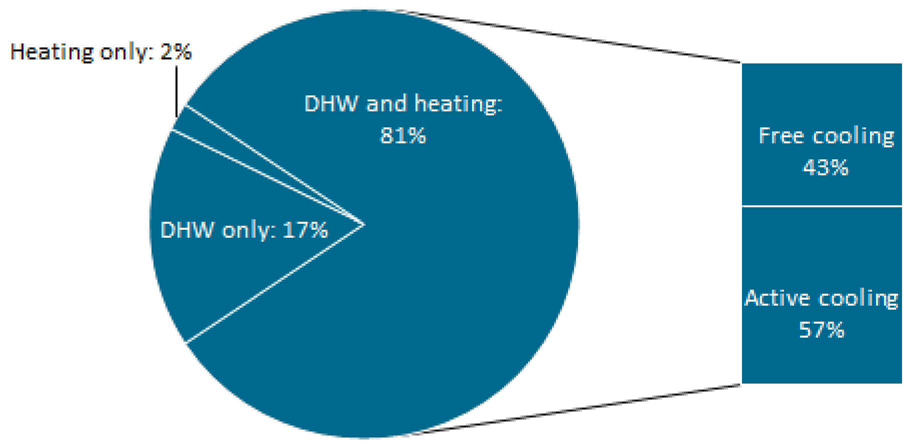

Figure 2: Intended applications of the reviewed SHP systems

Analysing the systems, the following principal operation possibilities or operation modes were observed:

- combination of solar thermal and heat pump where both subsystems deliver heat to a common storage but do not interact otherwise ("system combination" in Figure 3 or "parallel systems" in [5]);
- integration of solar thermal and heat pump where both subsystems can interact in order to increase the temperature of the heat pump source ("system interaction" in Figure 3 or "serial systems" in [5]:

- the heat from the solar thermal system is used to regenerate the heat pump source when either there is a surplus of useful heat (e.g. warm, sunny days) or the temperature level of the heat provided by the solar thermal system is insufficient for direct use. The heat source can be e.g. a low temperature storage or a ground coupled collector ("passive interaction" in Figure 3);
- the heat from the solar system is used directly as the source of the heat pump while it is in operation ("active interaction" in Figure 3). It can increase the temperature of the primary source (e.g. pre-heating of the ambient air) or it can be the sole heat source (e.g. direct evaporation in the collectors or heat transfer to the evaporator over a heat transfer fluid).

Some of the systems can operate in more than one of the modes described, depending on the hydraulic configuration and control strategies implemented by the manufacturer. An overview of the operation modes is shown in Figure 3. The nomenclature from this figure is used in the further text with some references to the nomenclature of the questionnaire (Annex 1).

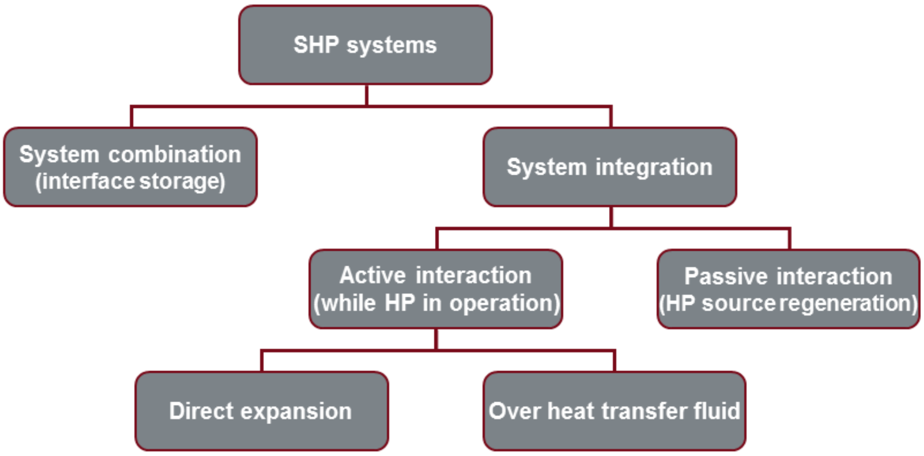

Figure 3: Operation modes of SHP systems covered by the survey

From the collected systems, 56 % are designed to operate as a combination where the heat pump and the solar thermal subsystems do not interact, but deliver heat to a common storage tank. In the questionnaire (Annex 1), this configuration is referred to as "not fully integrated". In the remaining 44 % of the systems, the solar thermal and the heat pump subsystems have a higher level of integration – they can interact in different manners, as explained above. These systems are referred to in the questionnaire as "system integration".

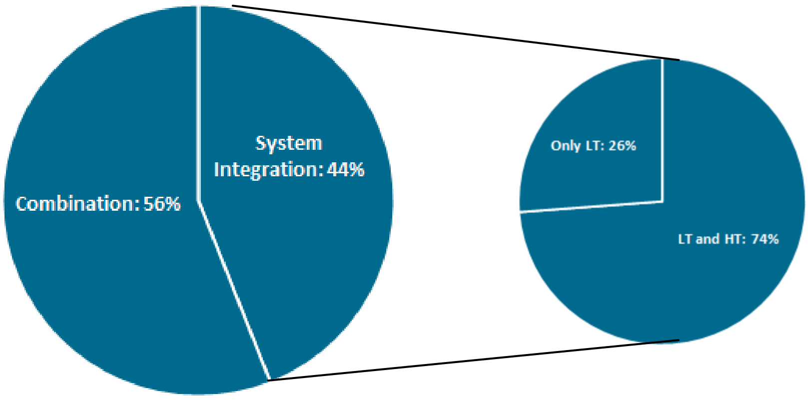

Figure 4: SHP system configuration

In about a quarter (26 %) of the “integrated” systems, the solar heat was used only as a low temperature (LT) heat at the evaporator for the heat pump. In other systems, solar heat was also directly used at higher temperature (HT) levels as the useful heat for DHW and/or heating. Classification of SHP systems by basic configuration is shown in Figure 4.

In about 70 % of the analysed systems with high level of integration, the solar heat could directly be used as the source for the heat pump, either indirectly, over a heat transfer fluid (57 %), for ambient air preheating, or through direct expansion in the solar collector (14 %), Figure 5. In about 20 % of the systems, the solar heat could either be used directly at the evaporator of the heat pump or stored for later usage, depending on the current demand. As low temperature storage, mostly ground is used. However, there are 10 systems among the collected ones with a sensible (8) or latent (2) heat storage as the heat source for the heat pump.

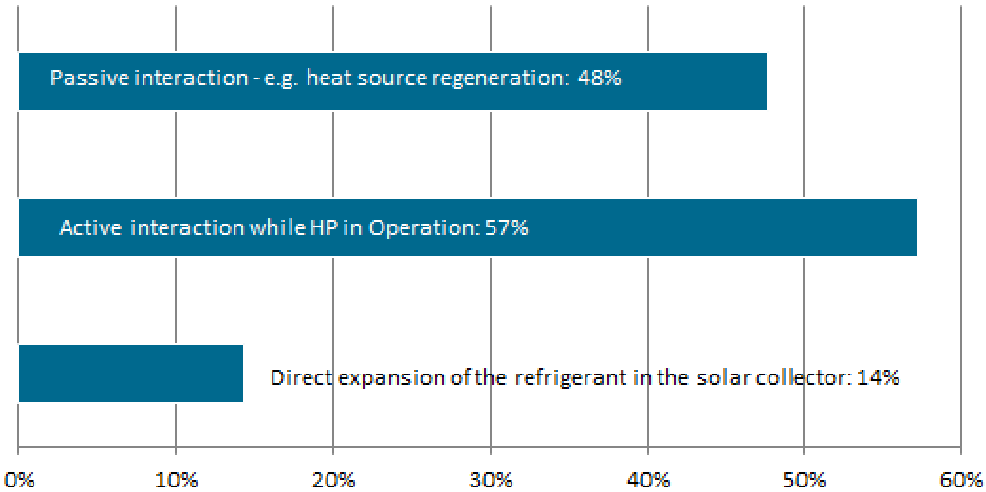

Figure 5: Coupling of solar and heat pump subsystems in integrated configurations

In combined systems, the most common heat sources for the heat pump are ground (37 %) and ambient air (48 %). Only 4 % of the products are designed for groundwater. There are 13 % of the systems which have an integrated air-handling function and they use exhaust air as heat source. Full overview is shown in Figure 6.

In these systems, only glazed flat plate collectors were used. In integrated systems, different collector types were used, according to the system configuration, Figure 7. Almost a third (31 %) of these systems have unglazed collectors.

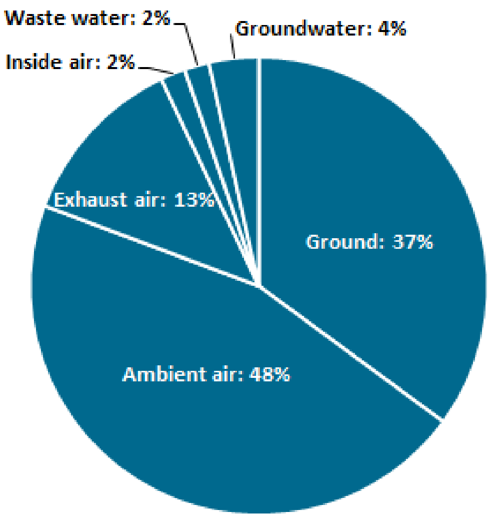

Figure 6: Heat sources for heat pump in combined systems

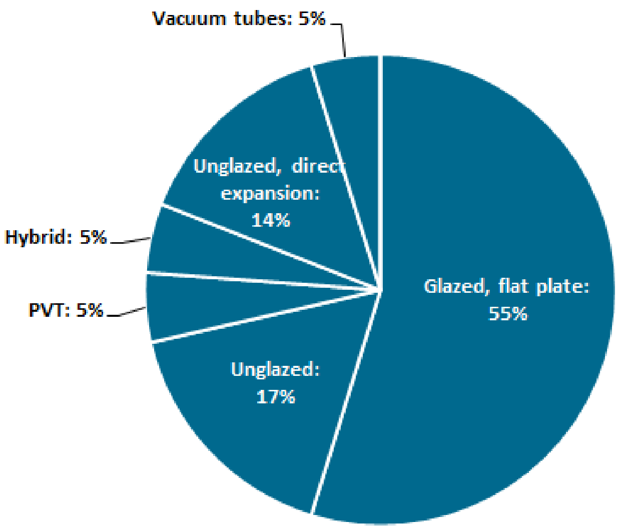

Figure 7: Collector types of integrated SHP systems

References

[1] Jordan, R. C., Threldeld, J. L., 1954, Design and economics of solar energy heat pump systems. ASHVEJ. 26, 122-130 (1954).

[2] Freeman, T.L., Mitchell, J.W., Audit, T.E., 1979, Performance of combined solar-heat pump systems, Solar Energy, Volume 22, Issue 2, 1979, pp. 125-135

[3] Hino T., 1984, “THE SOL-AIR HEAT PUMP SYSTEM,” Solar Engineering-1984, The American Society of Mechanical Engineers, pp. 435-443.

[4] Henning, H.-M., Miara, M., 2009, Kombination Solarthermie und Wärmepumpe - Lösungsansätze, Chancen und Grenzen, Proceedings of the 19. Symposium Thermische Solarenergie, Kloster Banz, Bad Staffelstein, Germany, pp.156-161

[5] Frank, E., Haller, M., Herkel, S., Ruschenberg, J., 2010, Systematic classification of combined solar thermal and heat pump systems. Proc. of the International Conference on Solar Heating, Cooling and Buildings 2010, Graz, Austria

[6] Malenković, I., 2012, Review on testing and rating procedures for solar thermal and heat pump systems and components. Technical Report 5.1.2, part of Deliverable 5.1 of the project QAiST – Quality Assurance in Solar Heating and Cooling Technology (Contract No. IEE/08/593/SI2.529236)

[7] Bonk, S., Loose, A., Schmidt, C., Riederer, P., Haberl, R., Haller, M., 2012, Report on testing procedures for SHP systems. Technical Report 5.1.4, part of Deliverable 5.1 of the project QAiST – Quality Assurance in Solar Heating and Cooling Technology (Contract No. IEE/08/593/SI2.529236)

Annex I: Questionnaire for the overview of existing SHP systems

Questionnaire for the data collection on existing solar and heat pump systems

The QAiST project

The long term objective of the QAiST project is to prepare the quality assurance framework so that the European solar thermal heating and cooling industry can provide a sustainable contribution to the targets agreed by the member states (20% of RES by 2020) and become a technological world leader. The participants in the project are leading European institutes working in the field of solar thermal energy.

The project is financed through the Intelligent Energy Europe (IEE) funding scheme. The project leader is the European Solar Thermal Industry Federation (ESTIF).

For more information on the project and the participants, please visit the project web presentation:

http://www.estif.org/projects/ongoing_projects/qaist/project_summary/

Purpose of the enquiry

One of the objectives of the project is to develop basic sets of requirements and test methods for emerging applications, one of them being the combination of solar thermal and heat pumps. With the help of this questionnaire, standardised information will be gathered on different configurations of this type of systems. Subsequently, this data will be statistically evaluated in order to obtain better understanding of different possibilities of integration, usage of components, applications etc. By better understanding the systems, we will be able to propose appropriate testing and rating standards, which will help the technology to improve its position on the market.

Data anonymity

All data will be use for scientific purposes only and will not be shared with or given to third parties outside the project consortium. The data will be statistically evaluated and the results published in the final project report without any references to the manufacturers. However, if your company/institute has interest in showing a system at one of the project meetings or at national workshops organised within the project, you can send us appropriate material and provide us your written approval to do so.

Instructions

Please fill in the provided questionnaire by ticking the boxes beside the respective category. Where needed, please fill in the text box (indicated yellow).

For configuration classification within the table in chapter 2, a short description of the categories is provided on the next page. More than one category can apply for one system.

Apart from the questionnaire, any further information on the system (schematic, drawings, performance data, product sheets, publications etc.) that you would be willing to share would be very helpful.

For any further questions regarding the purpose of the project, the survey, this questionnaire or data handling issues, please contact the Task leader within the QAiST project:

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Intelligent Energy Europe
Project IEE/08/593/SI2.529236

1. System classification

A rough classification of integrated solar thermal and heat pump systems can be carried out as shown in Figure 1:

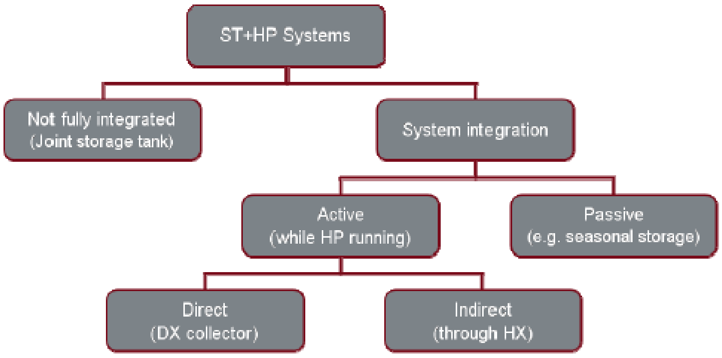

Figure 1: Classification of solar thermal and heat pump systems

Not fully integrated: Both solar thermal system and the heat pump supply hot water to the storage. Both systems operate independently and do not interact.

System integration: Solar thermal system and the heat pump interact in such a way, that the performance of one or both of them is influenced.

Passive: The solar system is contributing to the increase of the source temperature of the heat pump by storing the excess heat to a seasonal storage, e.g. soil.

Active: The heat from the solar system is directly supplied to the heat pump source.

Direct: The refrigerant of the heat pump evaporates directly in the solar collector.

Indirect: The heat transfer fluid of the heat pump source is completely or partially heated by the solar system.

Acknowledgment

The questionnaire in Chapter 3 was developed on the basis of the following publications, with the previous approval from the authors: Haller, M.Y., Frank, E., Trinkl, C., Zörner, W., 2010, Systematische Gliederung der Systemkombination von solarthermischen Anlagen und Wärmepumpen. Proceedings 20. Symposium Thermische Solarenergie, OTTI, Bad Staffelstein, Germany

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2. General data

Before starting to fill in the form, please protect the form by pressing the 🔒 button in the "Forms" taskbar. For inserting additional material in Chapter 4, please deactivate the protection.

Company name:	[TEXT]
Country:	[TEXT]
Contact:	
• Name	[TEXT]
• Telephone	[TEXT]
• Email	[TEXT]
Product name:	[TEXT]
On the market since:	[TEXT]
Capacity:	
• Domestic hot water	[TEXT]
• Heating	[TEXT]
• Cooling	[TEXT]
Intended application:	
• New buildings only	☐
• New or retrofit buildings	☐
Configuration classification:	(multiple choice)
• Not fully integrated	☐
• System integration	☐
• Passive	☐
• Active	☐
• Direct	☐
• Indirect	☐
• Other	☐ (please describe in Chapter 5)

3. System and configuration data

1	Climate		
1.1	Country	[TEXT]	
1.2	Nearest city or GPS coordinates	[TEXT]	
2	Application / Demand		
2.1	Domestic hot water (DHW)		☐
2.2	Heating, hydronic		☐
2.3	Heating, air		☐
2.4	Cooling		☐

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3	**Heat sources for the heat pump**		
3.1	Direct expansion in collector	☐	
3.2	Solar heat direct	☐	
3.3	Heat storage	☐	
3.4	Outside air	☐	
3.5	Exhaust air	☐	
3.6	Inside air (e.g. cellar)	☐	
3.7	Ground	☐	
3.8	Ground water	☐	
3.9	Waste water	☐	
4	**Heat sinks for the heat pump**		
4.1	DHW (please indicate T in °C)	☐	[Supply T]
4.2	Low temperature heating (≤35°C)	☐	[Supply T]
4.3	Medium temperature heating (≤45°C)	☐	[Supply T]
4.4	High temperature heating (>45°C)	☐	[Supply T]
5	**Heat pump refrigerant**		
5.1	Type (e.g. R407C)		[TEXT]
6	**Type of the solar collector**		
6.1	Direct expansion collector	☐	
6.2	Non-glazed	☐	
6.3	Flat (glazed)	☐	
6.4	Vacuum tubes	☐	
6.5	Air collector	☐	
6.6	Hybrid	☐	
6.7	Polymer	☐	
6.8	PVT	☐	
6.9	Other		[TEXT]
7	**Heat sinks of the solar system**		
7.1	DHW	☐	
7.2	Heating	☐	
7.3	HP evaporator (without storage)	☐	
7.4	Active ground regeneration	☐	
7.5	Cold storage HP	☐	
8	**Storage on the cold side of the heat pump**		
8.1	Sensible heat (water)	☐	
8.2	PCM (incl. ice)	☐	
8.3	Sorption	☐	
8.4	Seasonal storage	☐	

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9	Heat storage		
9.1	Water	☐	
9.2	PCM	☐	
9.3	Ground	☐	
10	Additional heat sources		
10.1	Electricity direct	☐	
10.2	Oil	☐	
10.3	Gas	☐	
10.4	Biomass	☐	
10.5	Other (please indicate which)	☐	[TEXT]

4. Additional information (Schematics, data sheets etc.)

[TEXT]

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